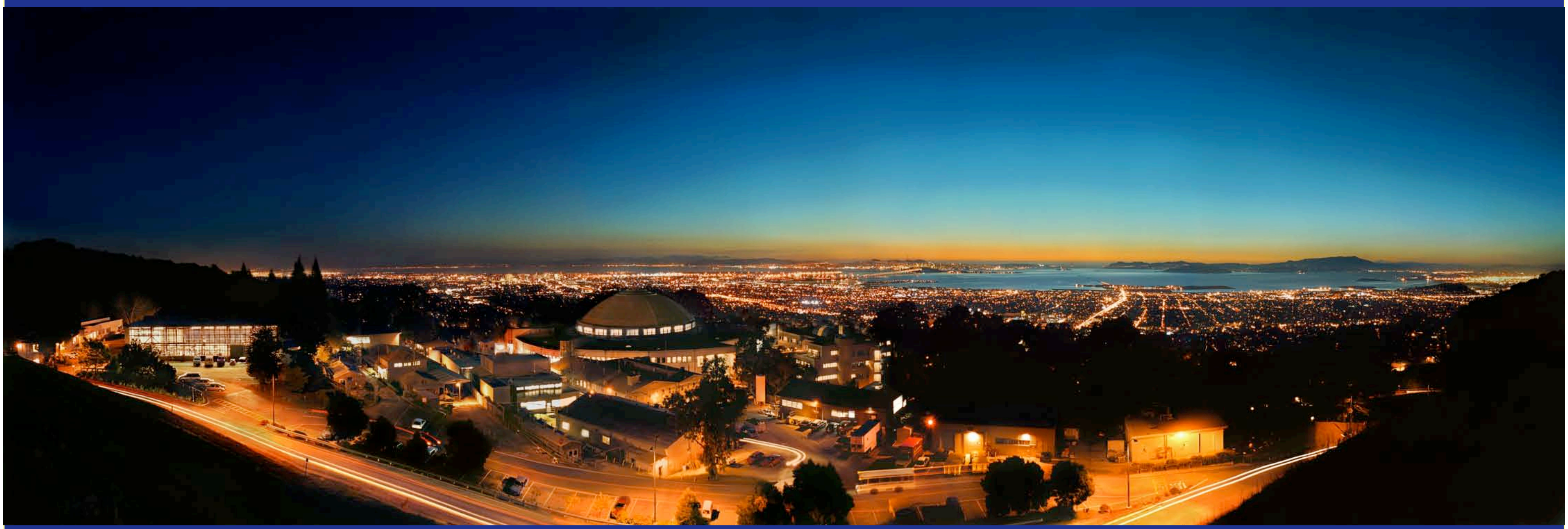
Energy Efficient Data Centers

Sacramento Municipal Utility District – April 17, 2007



William Tschudi

Ashok Gadgil

Arman Shehabi

Agenda

- Brief overview of LBNL data center energy efficiency research activities
- Data center resources
- Demonstration Projects
- Discussion

LBNL resources involved with Data Center energy efficiency

- Bill Tschudi
- Dale Sartor
- Steve Greenberg
- Tim Xu
- Evan Mills
- Bruce Nordman
- Jon Koomey
- Ashok Gadgil
- Paul Mathew
- Arman Shehabi

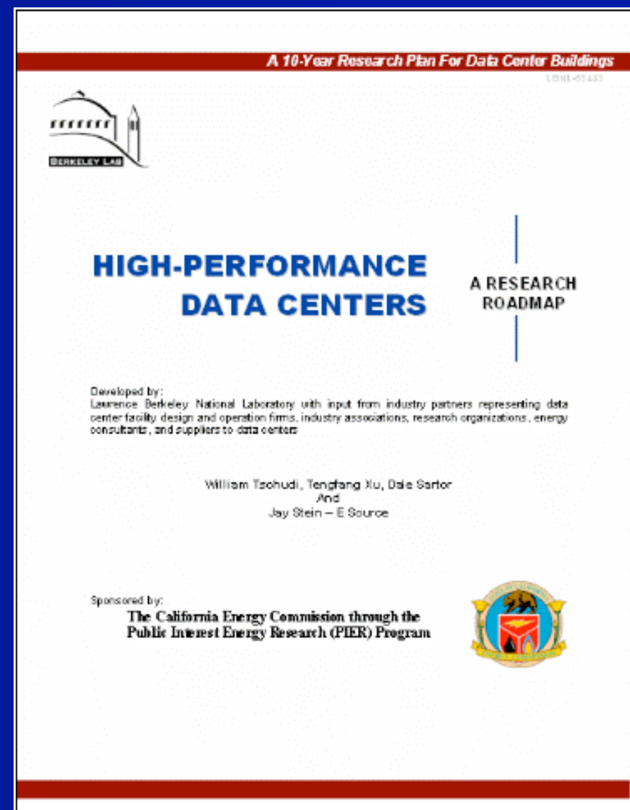
- Subcontractors
  - Ecos Consulting
  - EPRI Solutions
  - EYP Mission Critical Facilities
  - Rumsey Engineers
  - Syska & Hennesy

LBNL sponsors

- California Energy Commission – PIER program
- Pacific Gas and Electric Company
- New York State Energy and Development Agency (NYSERDA)
- US - Environmental Protection Agency
- US – Department of Energy

Data Center Research Roadmap

A “research roadmap” was developed for the California Energy Commission. This outlined key areas for energy efficiency research, development, and demonstration and includes strategies that can be implemented in the short term.



A 10-Year Research Plan For Data Center Buildings

BERKELEY LAB

HIGH-PERFORMANCE
DATA CENTERS

A RESEARCH ROADMAP

Developed by:
Laurence Berkeley National Laboratory with input from industry partners representing data center facility design and operation firms, industry associations, research organizations, energy consultants, and suppliers to data centers

William Tschudi, Tengfang Xu, Dale Sartor
And
Jay Stein – E Source

Sponsored by:
The California Energy Commission through the Public Interest Energy Research (PIER) Program

Data Center research activities

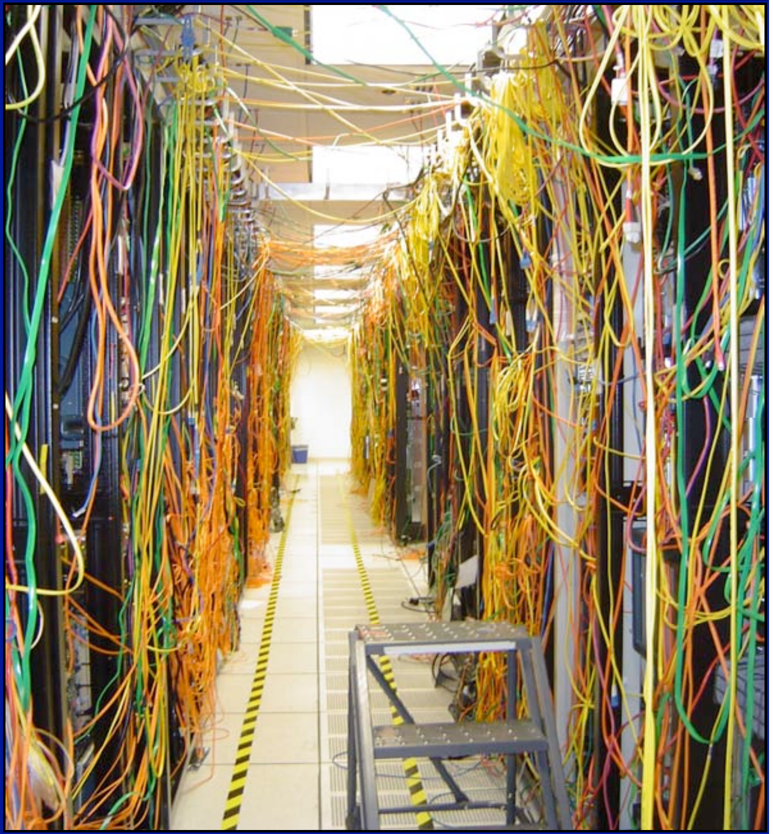
- Benchmarking and 23 data center case studies
- Self-benchmarking protocol
- Power supply efficiency study
- UPS systems efficiency study
- Standby generation losses
- Performance metrics – Computation/watt
- Market study
- EPA report to Congress

LBNL Data Center demonstration projects

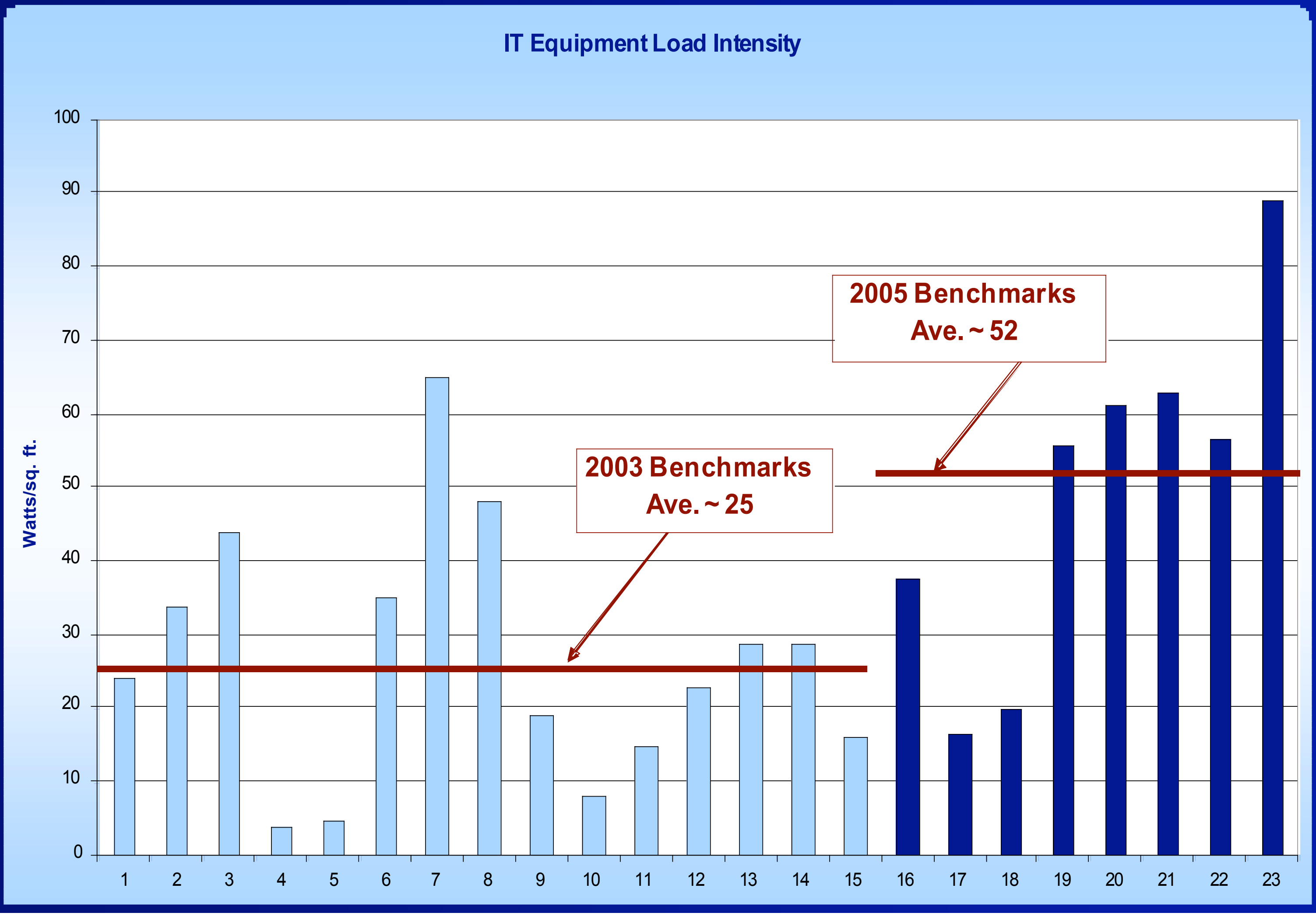
- Outside air economizer demonstration (PG&E)
  - Contamination concerns
  - Humidity control concerns
- DC powering demonstrations (CEC-PIER)
  - Facility level
  - Rack level
- "Air management" demonstration (PG&E)

Case studies/benchmarks

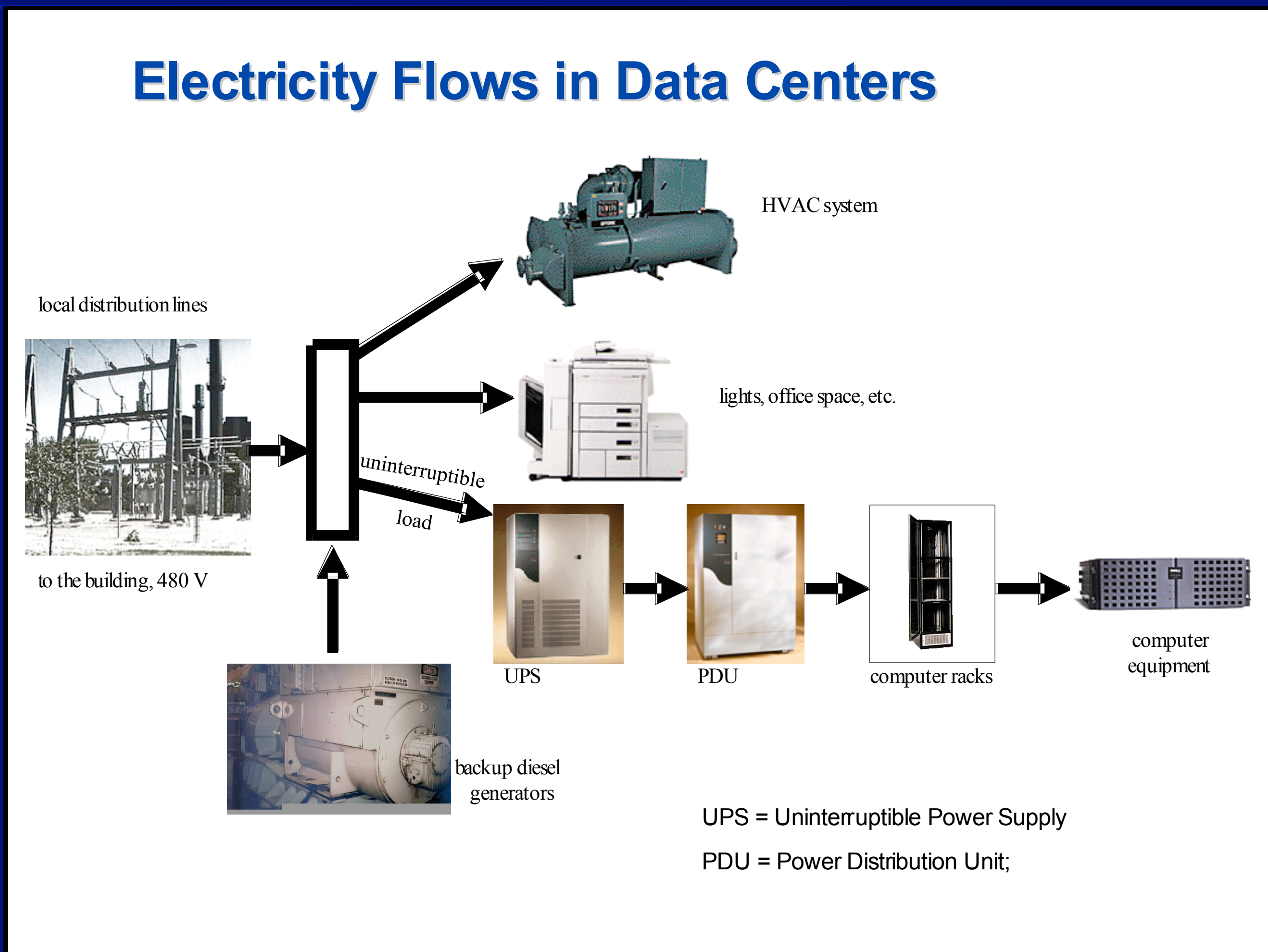
- Banks/financial institutions
- Web hosting
- Internet service provider
- Scientific Computing
- Recovery center
- Tax processing
- Storage and router manufacturers
- Computer animation
- others



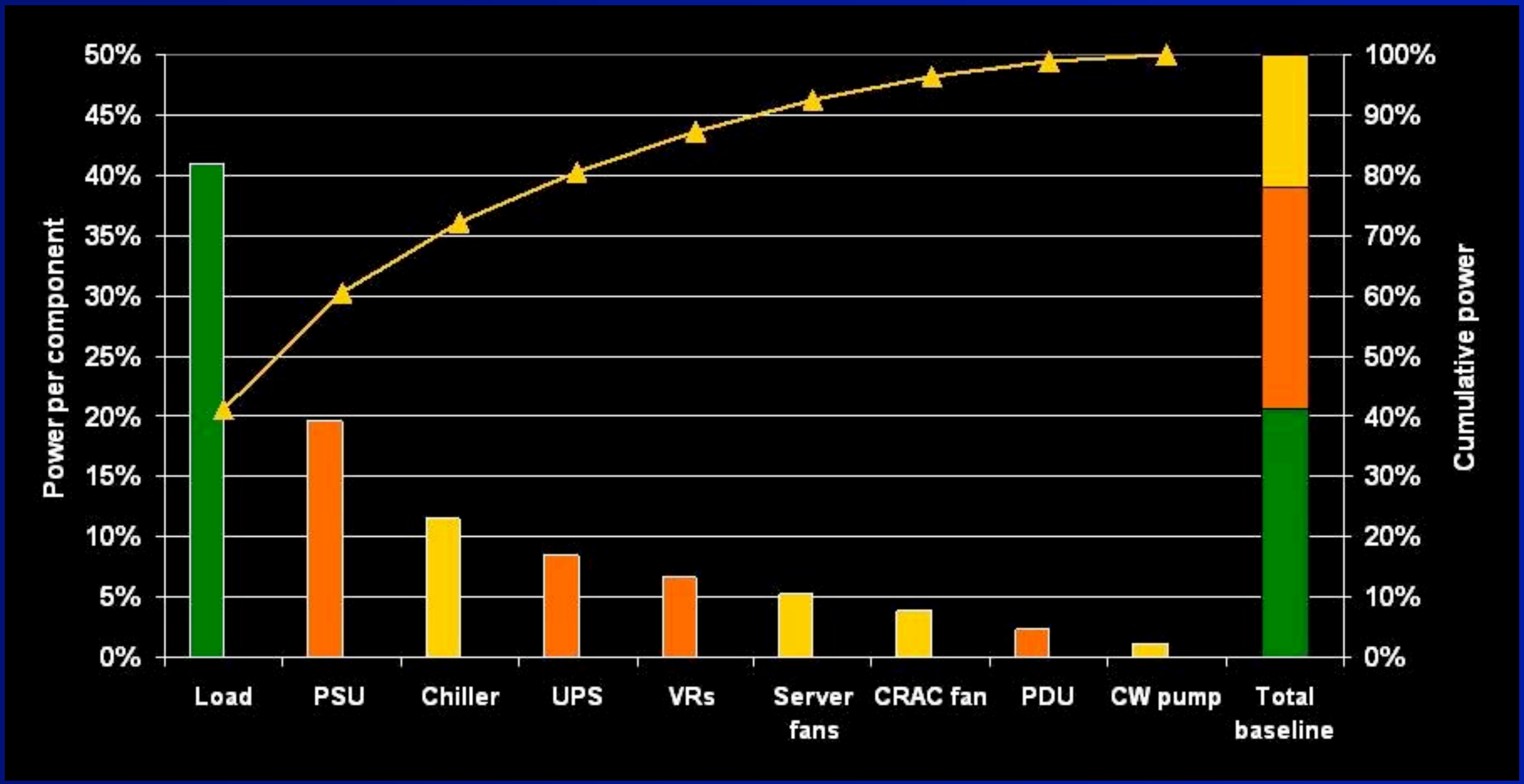
IT equipment load density



Benchmarking energy end use

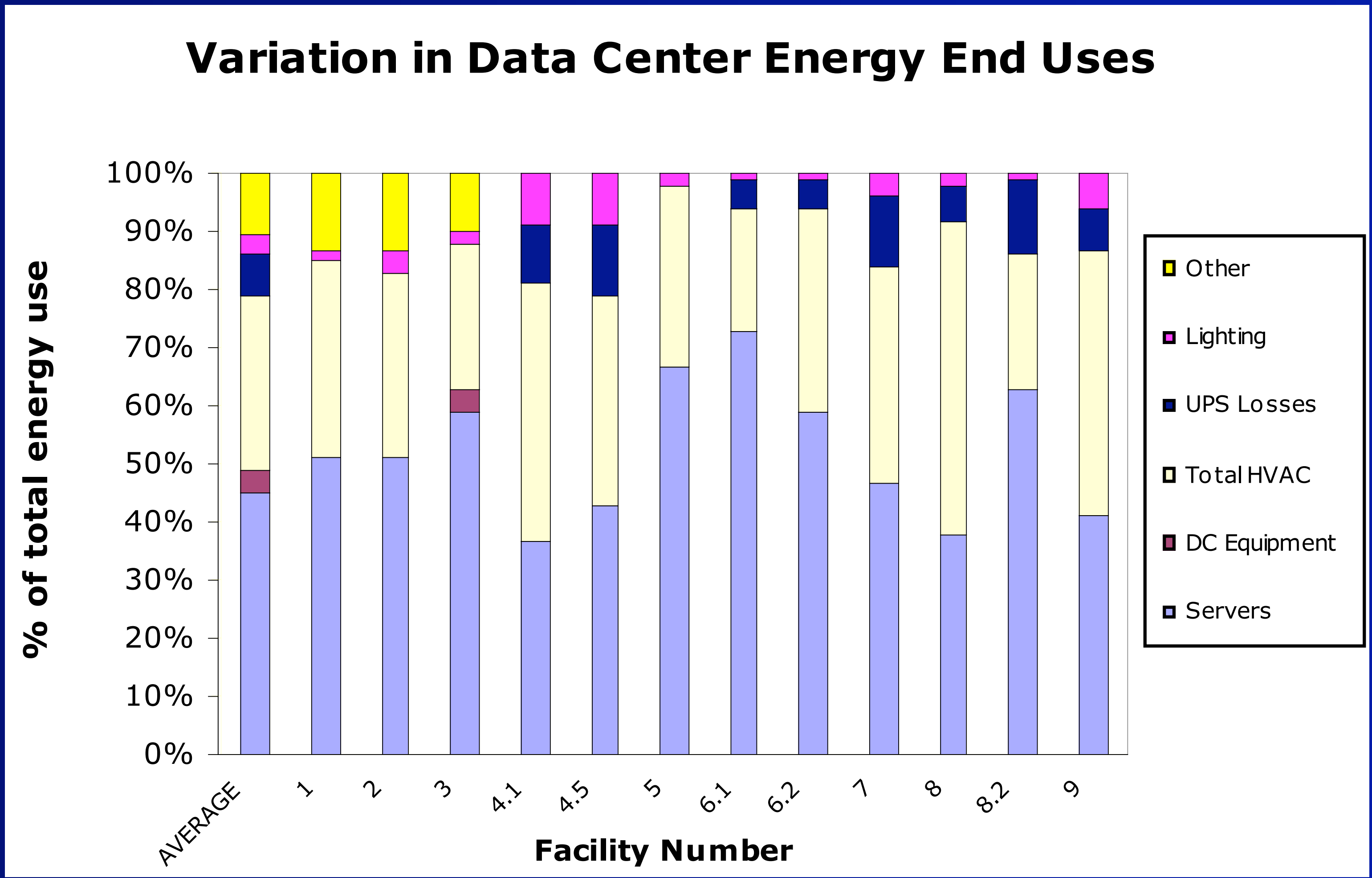


Overall power use in Data Centers



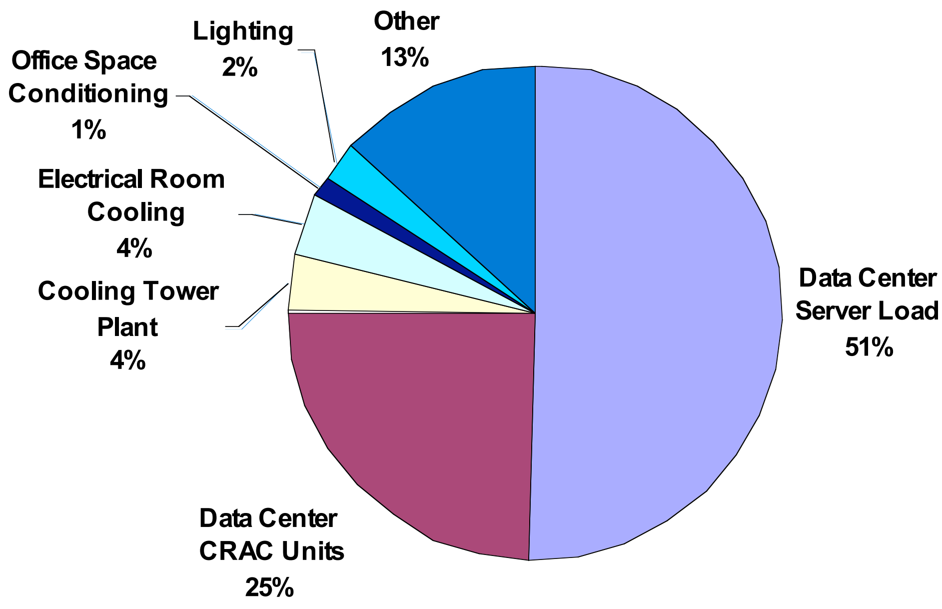
Courtesy of Michael Patterson, Intel Corporation

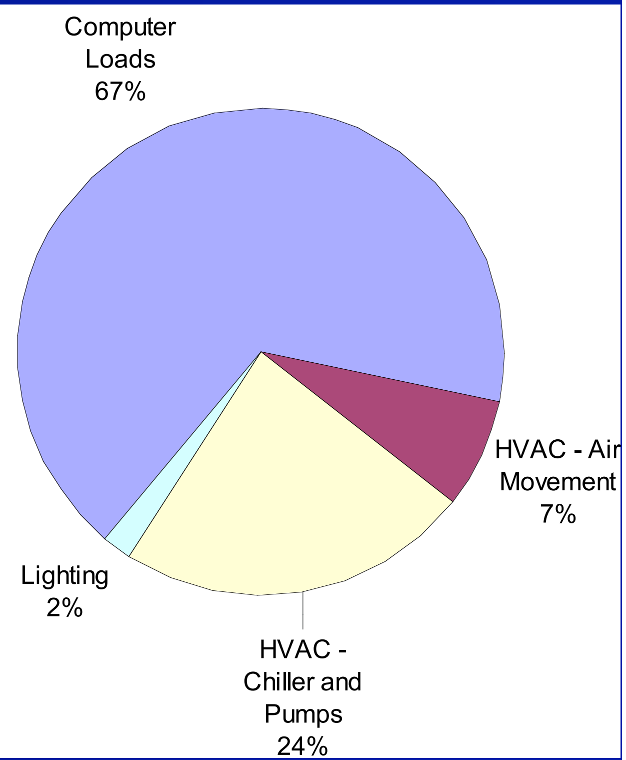
Data Center performance differences



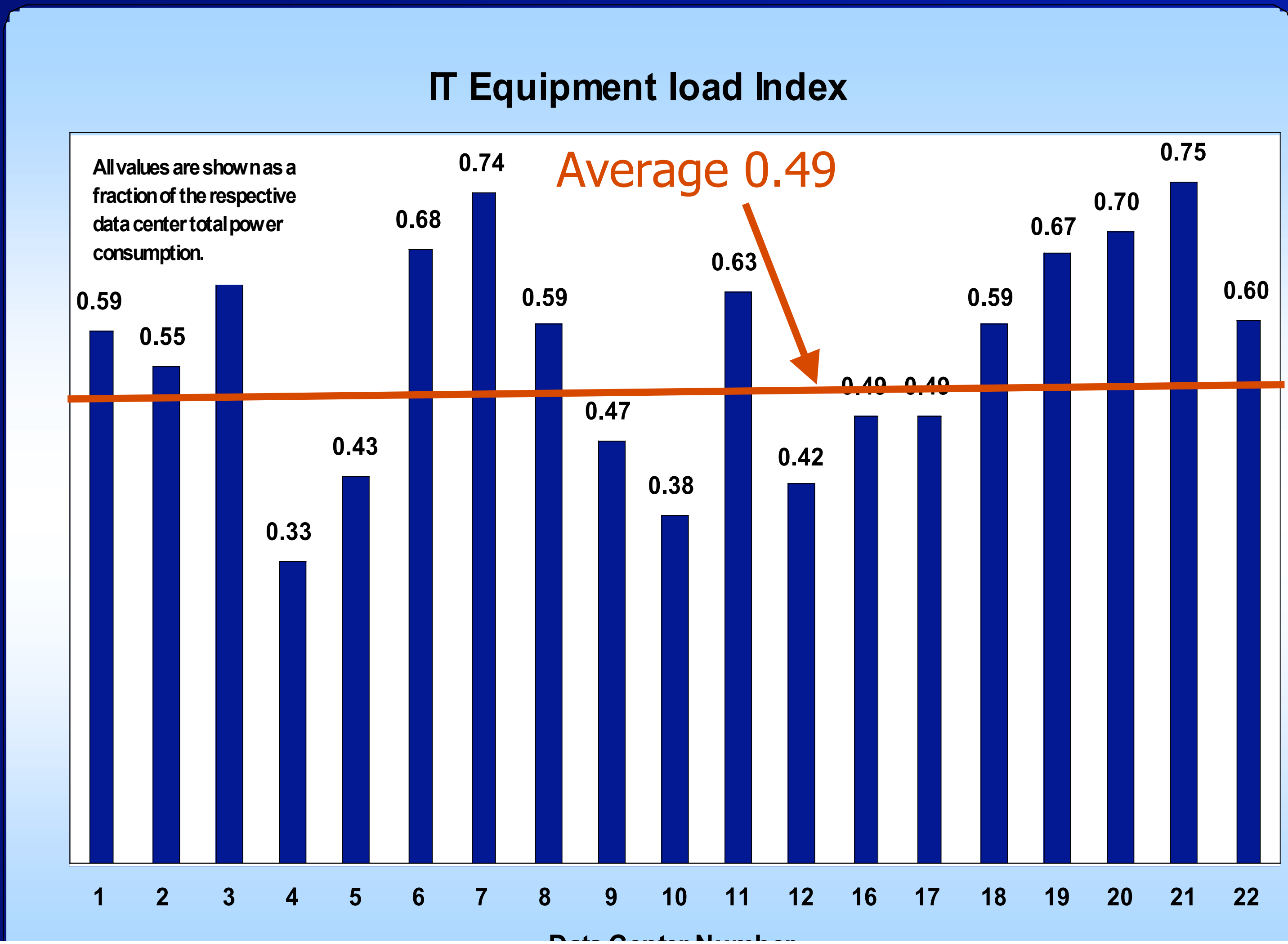
Performance varies

The relative percentages of the energy actually doing computing varied considerably.



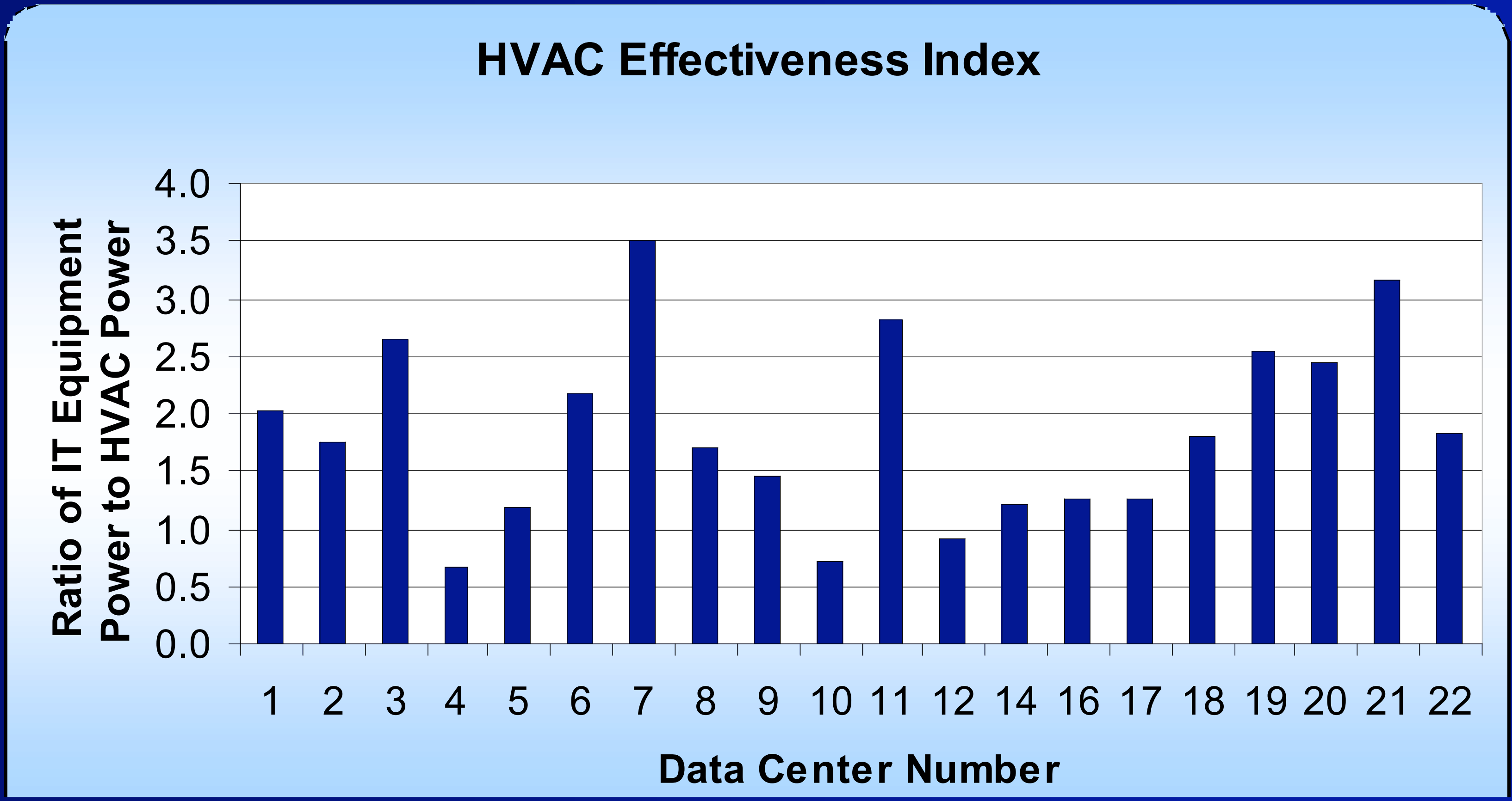


Percentage of power delivered to IT equipment



HVAC system effectiveness

We observed a wide variation in HVAC performance



Benchmark results were studied to find best practices

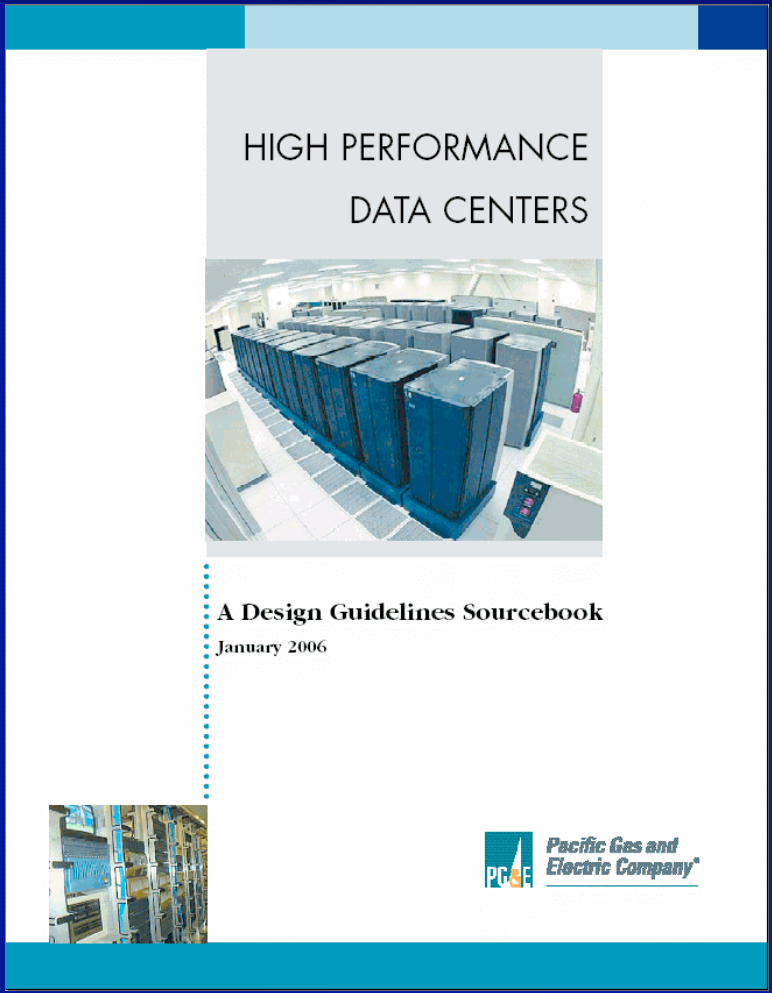
The ratio of IT equipment power to the total is an indicator of relative overall efficiency. Examination of individual systems and components in the centers that performed well helped to identify best practices.

Best practices topics identified through benchmarking

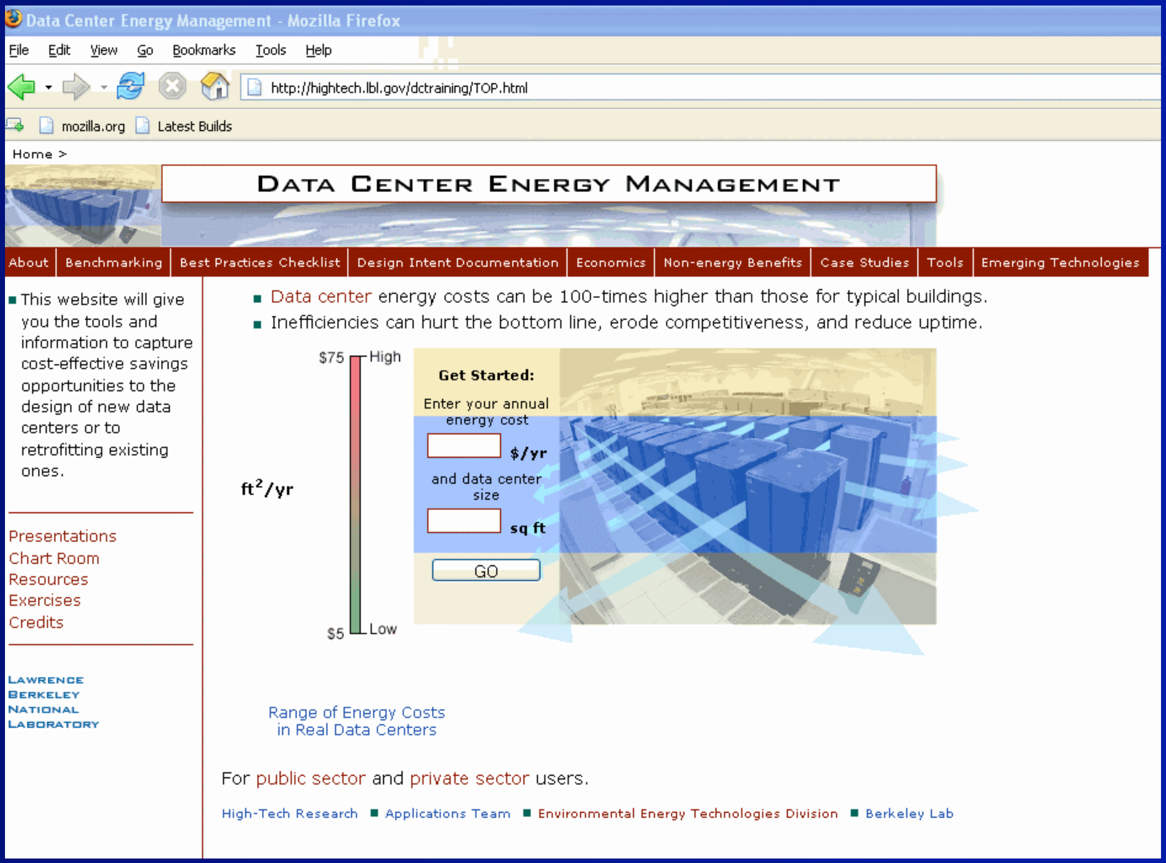
HVAC – Air Delivery – Water Systems		Facility Electrical Systems	IT Equipment	Cross -cutting / misc. issues
Air management	Cooling plant optimization	UPS systems	Power Supply efficiency	Motor efficiency
Air economizers	Free cooling	Self generation	Sleep/standby loads	Right sizing
Humidification controls alternatives	Variable speed pumping	AC-DC Distribution	IT equip fans	Variable speed drives
Centralized air handlers	Variable speed Chillers	Standby genera tion		Lighting
Direct liquid cooling				Maintenance
Low pressure drop air distribution				Commissioning/continuous benchmarking
Fan efficiency				Heat recovery
				Redundancies
				Method of charging for space and power
				Building envelope

Design guidelines were developed in collaboration with PG&E

Guides available through PG&E's Energy Design Resources Website



Design guidance is summarized in a web based training resource



http://hightech.lbl.gov/dctraining/TOP.html

Performance metrics

- Computer benchmark programs assess relative computing performance. Measuring energy use while running benchmark programs will yield Computations/Watt (similar to mpg)
- Energy Star interest
- First such protocol was issued for trial use

Encouraging outside air economizers

- Issue:
  - Many are reluctant to use economizers
  - Outdoor pollutants and humidity control considered equipment risk
- Goal:
  - Encourage use of outside air economizers where climate is appropriate
- Strategy:
  - Address concerns: contamination/humidity control
  - Quantify energy savings benefits

Project objectives

- Identify potential failure mechanisms
- Measure contamination levels in data centers
- Observe humidity control
- Evaluate economizer effect on contamination levels
- Compare particle concentrations to guidelines
- Document economizers use in data centers

Data center contamination guidelines

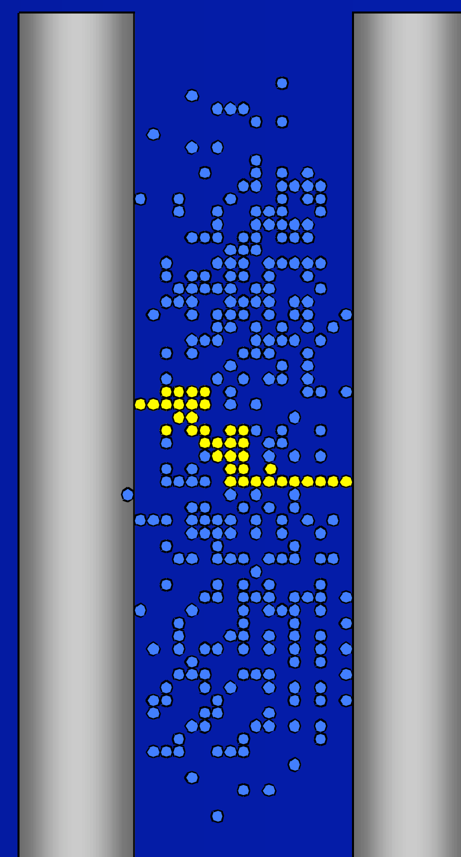
- Limited literature connecting pollutants to equipment failure
- ASHRAE Technical Committee
  - "Design Considerations for Data/Com Equipment Centers"
  - Guidelines for particles, gases, humidity
  - Industry Sources: Telcordia GR-63-CORE/IEC 60721-3-3
  - Designed for telephone switching centers
  - Based on research over 20 years old
- Primary concern: current leakage caused by particle bridging

Contaminants	Concentration
Airborne Particles (TSP)	$20\mu g/m^3$
Coarse Particles	$<10\mu g/m^3$
Fine Particles	$15\mu g/m^3$
Water Soluble Salts	$10\mu g/m^3$ max-total
Sulfate	$10\mu g/m^3$
Nitrites	$5\ \mu g/m^3$
Total	$55\ \mu g/m^3$

Particle bridging

Only documented pollutant problem

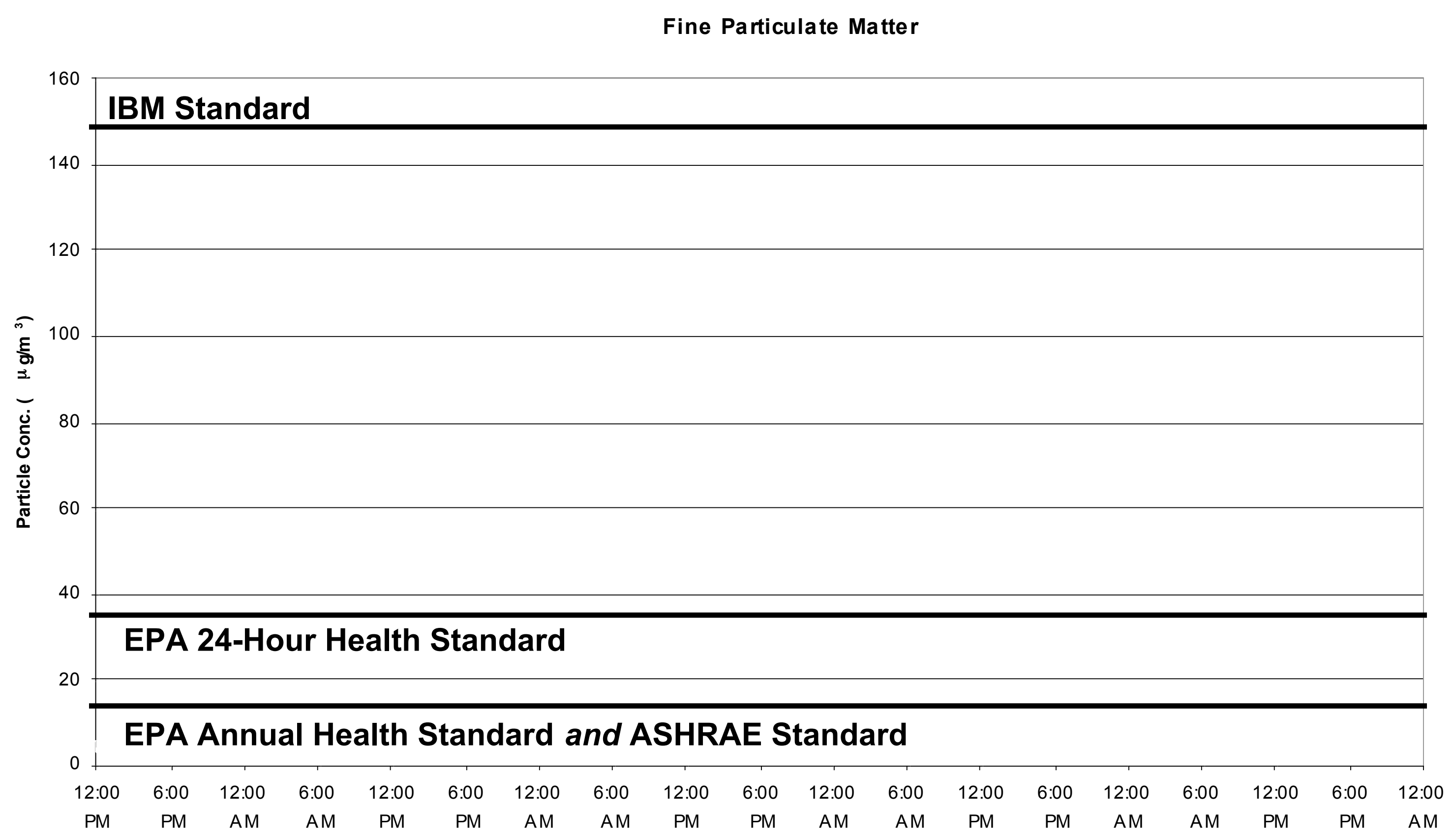
- Over time, deposited particles bridge isolated conductors
- Increased relative humidity causes particles to absorb moisture
- Particles dissociate, become electrically conductive
- Causes current leakage
- Can damage equipment



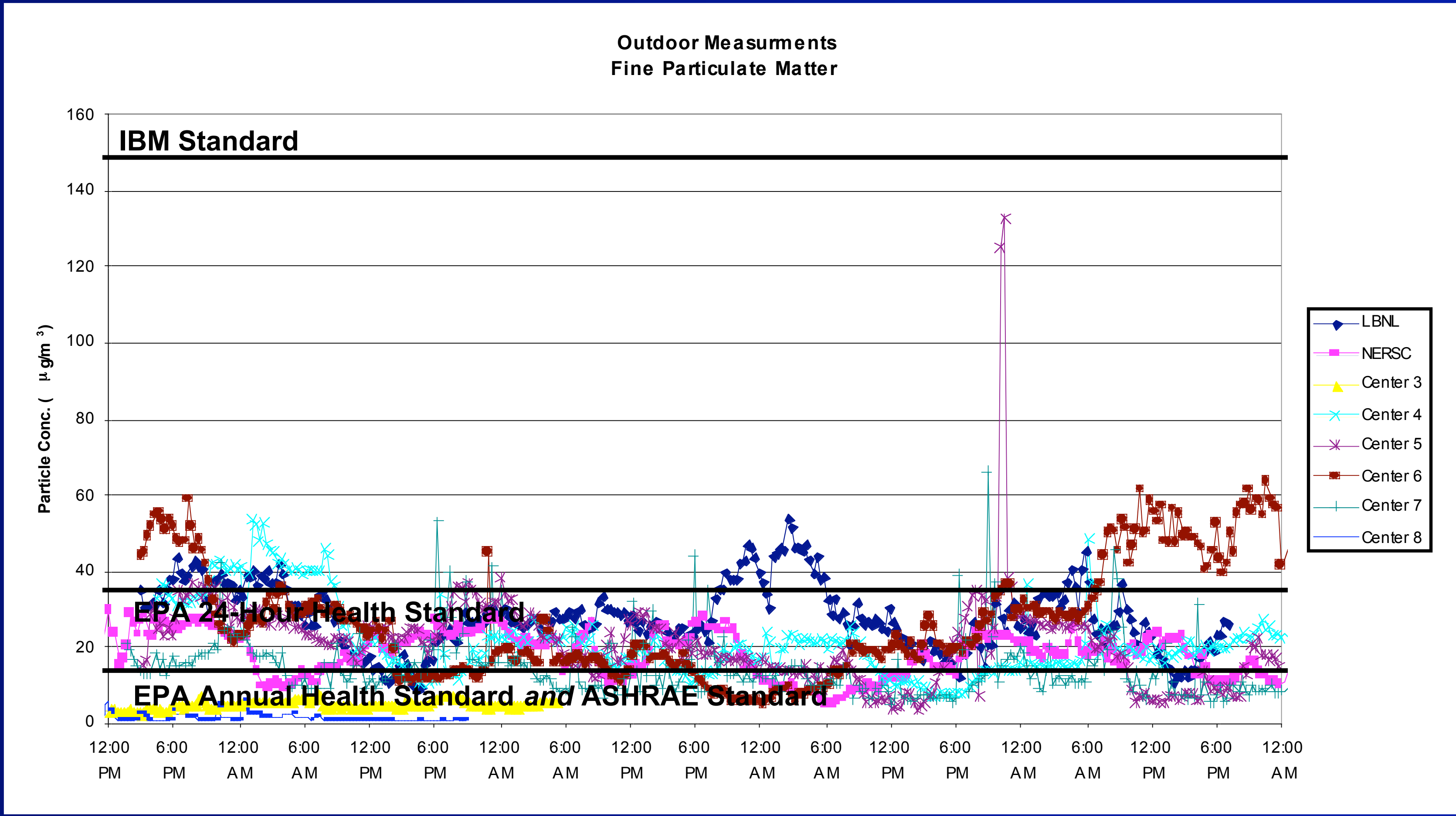
Particle measurements

- Measurements taken at eight data centers
- Approximately week long measurements
- Before and after capability at three centers
- Continuous monitoring equipment in place at one center (data collection over several months)

Some reference concentrations

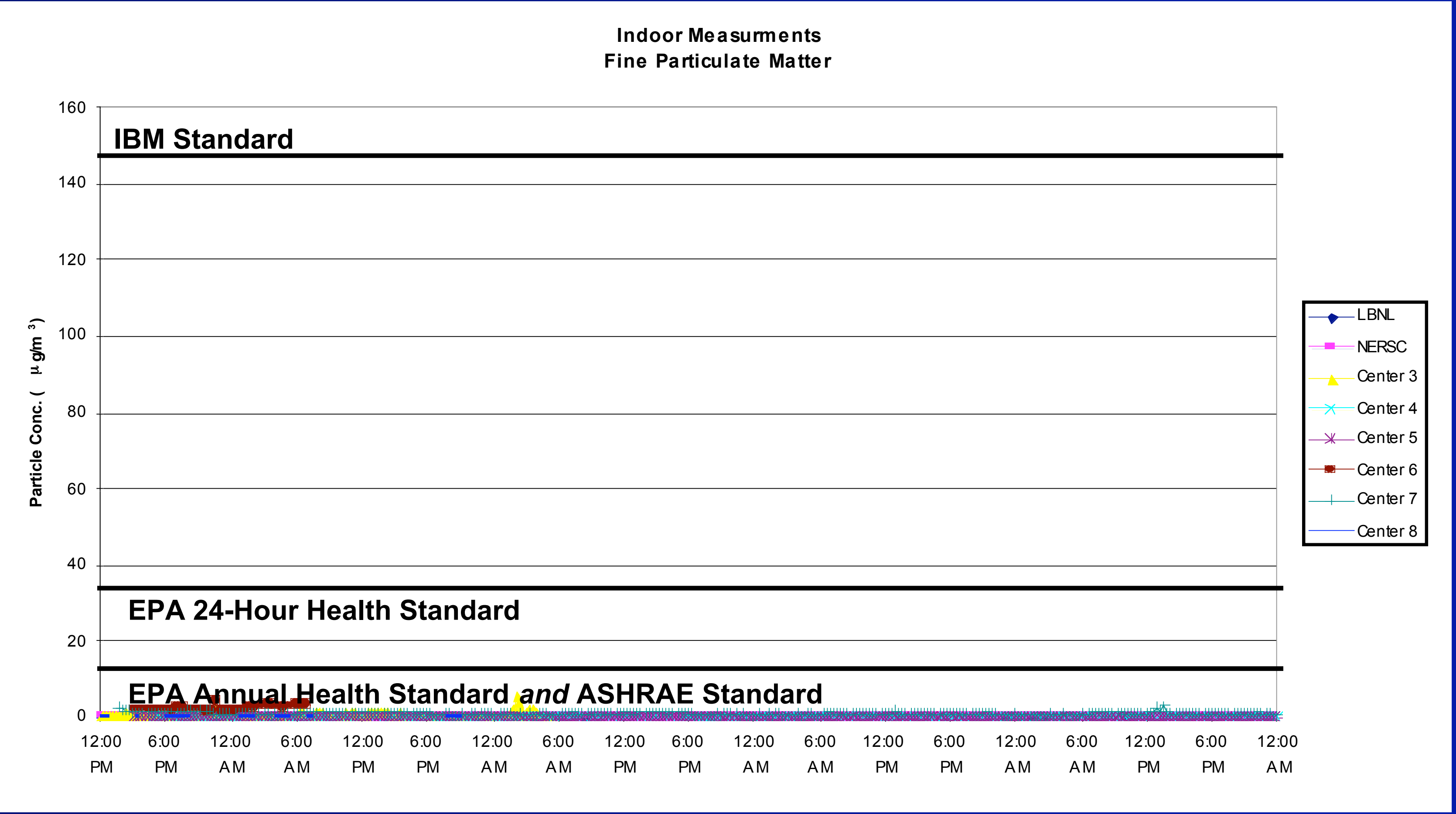


Outdoor measurements



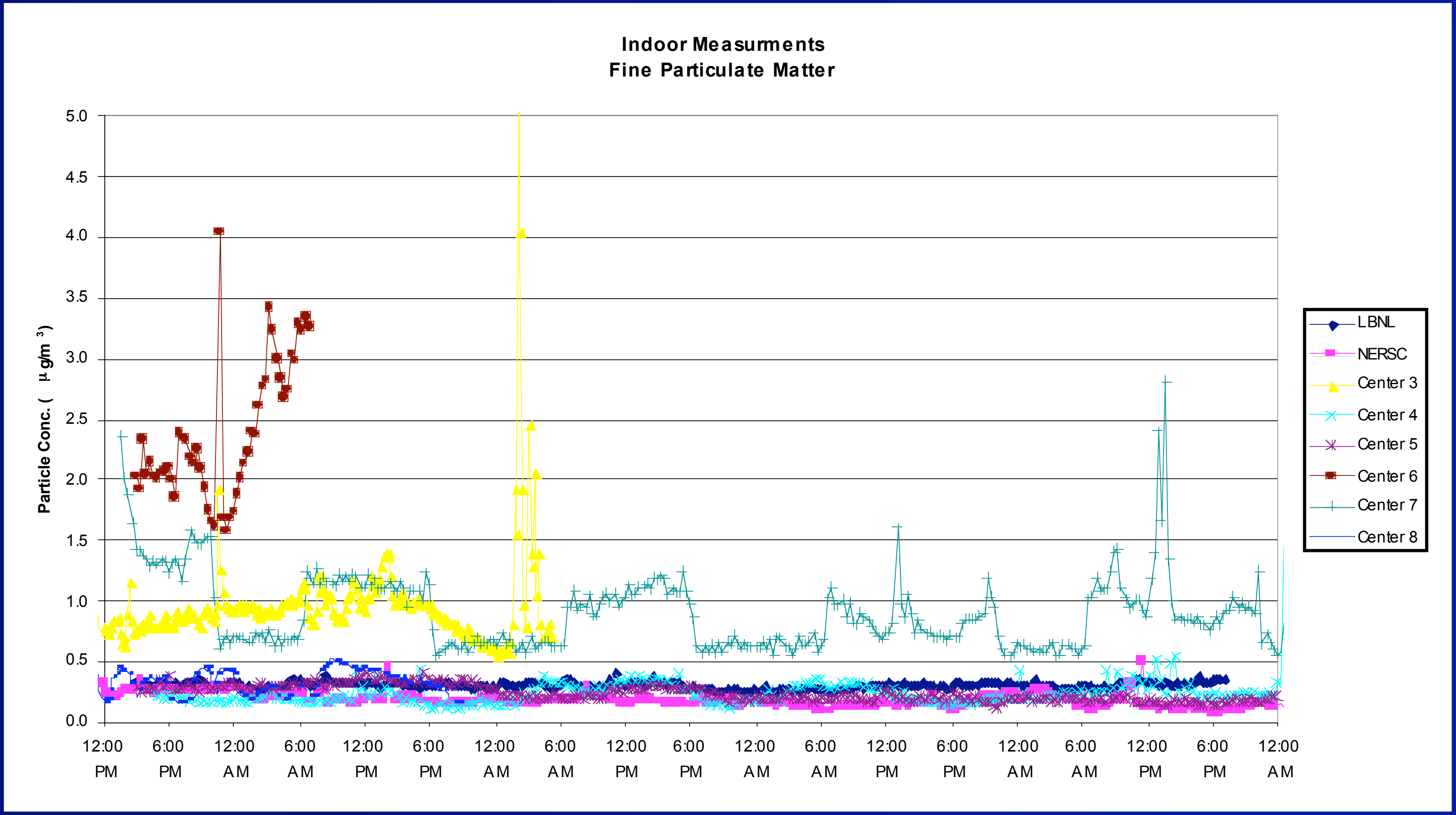
Note scale

Indoor measurements



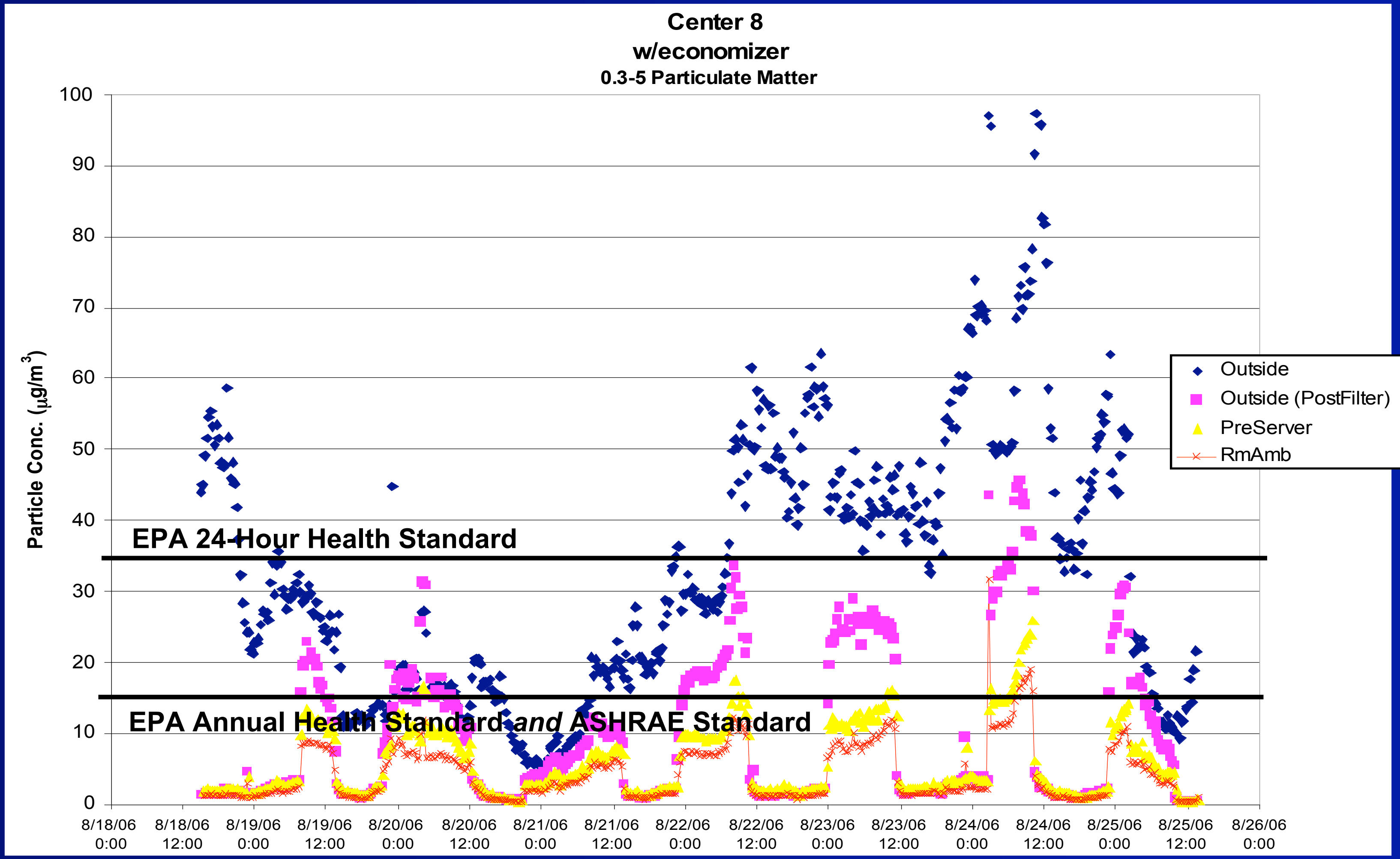
Note scale

Indoor measurements



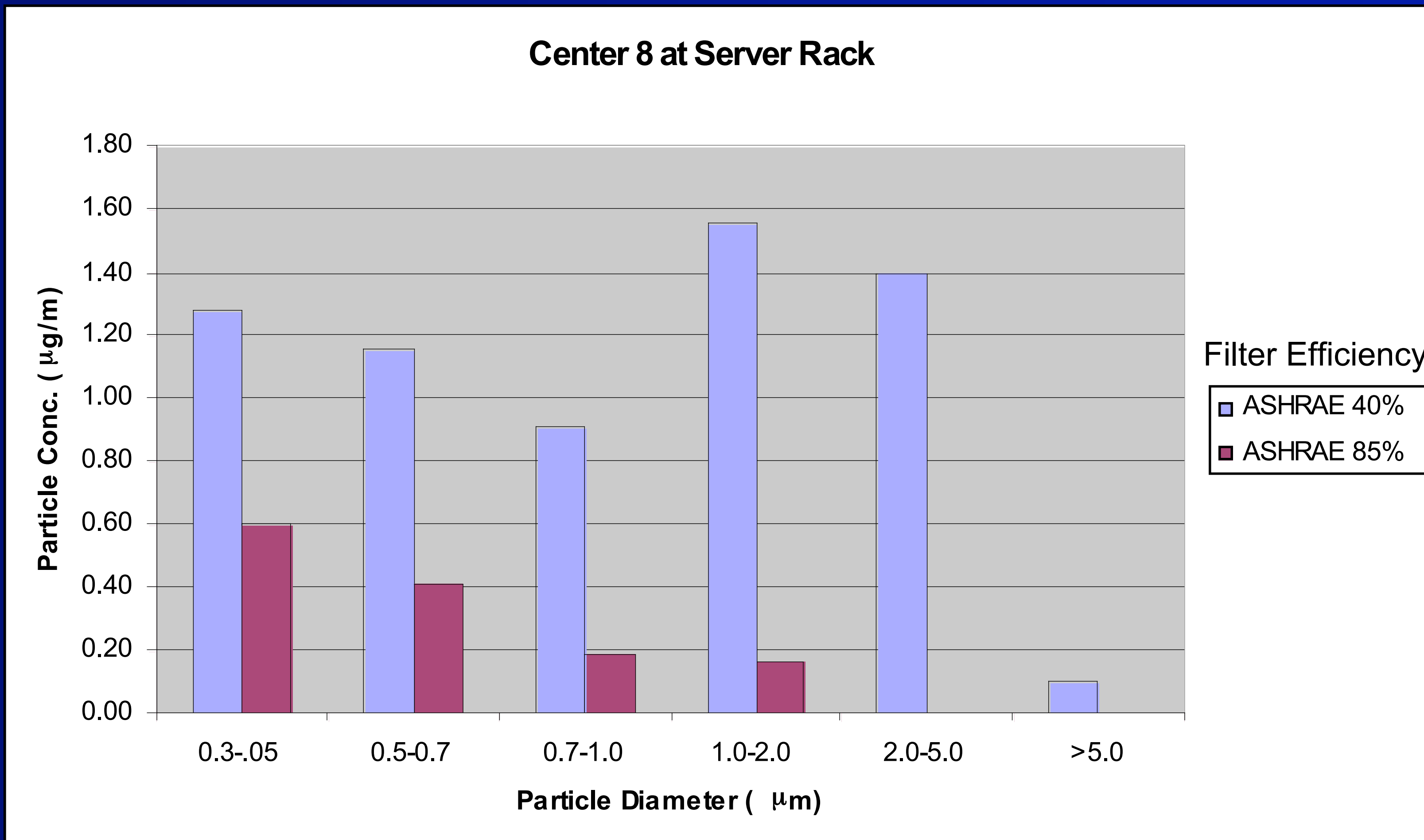
Note scale

Data center w/economizer

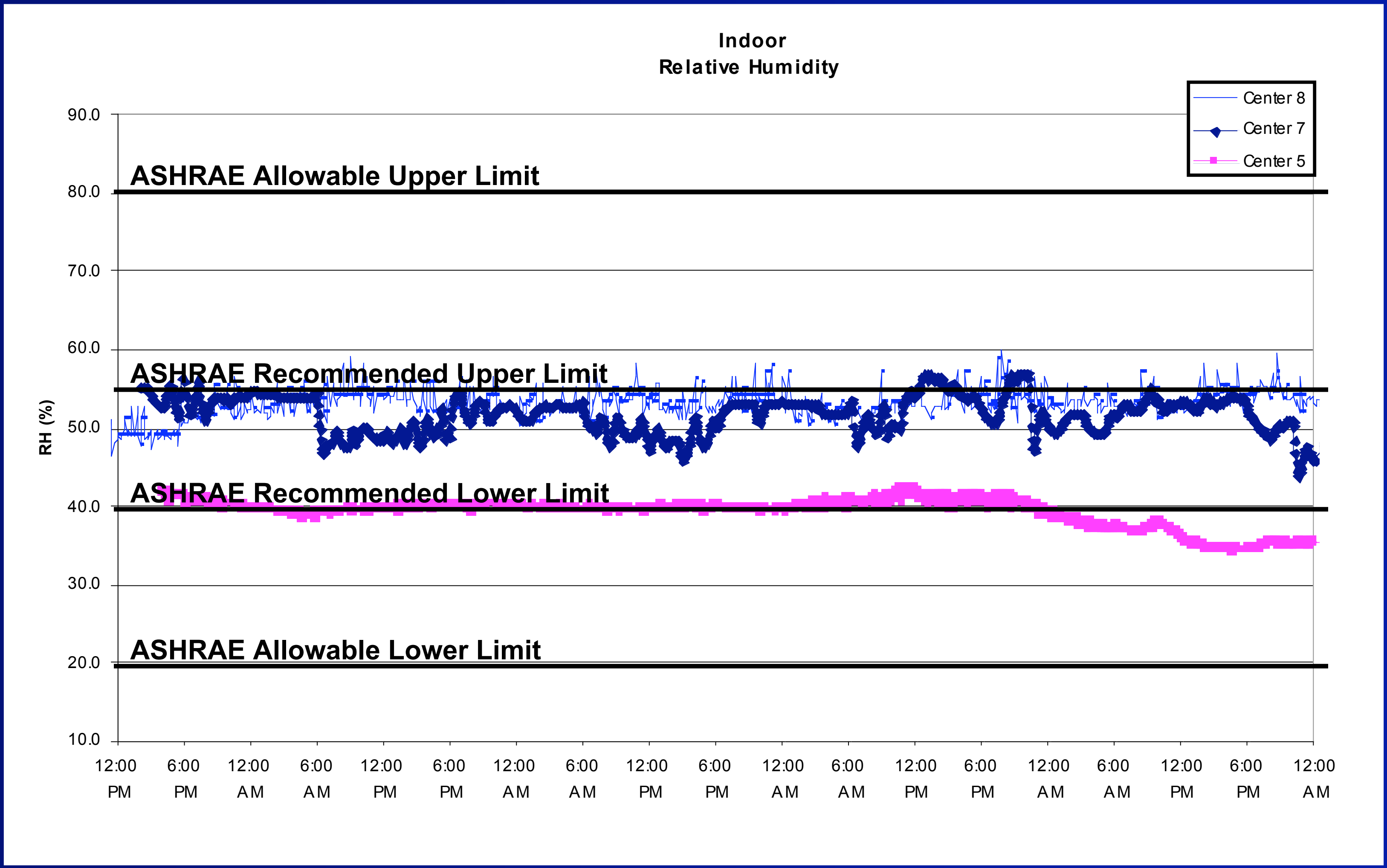


Note scale

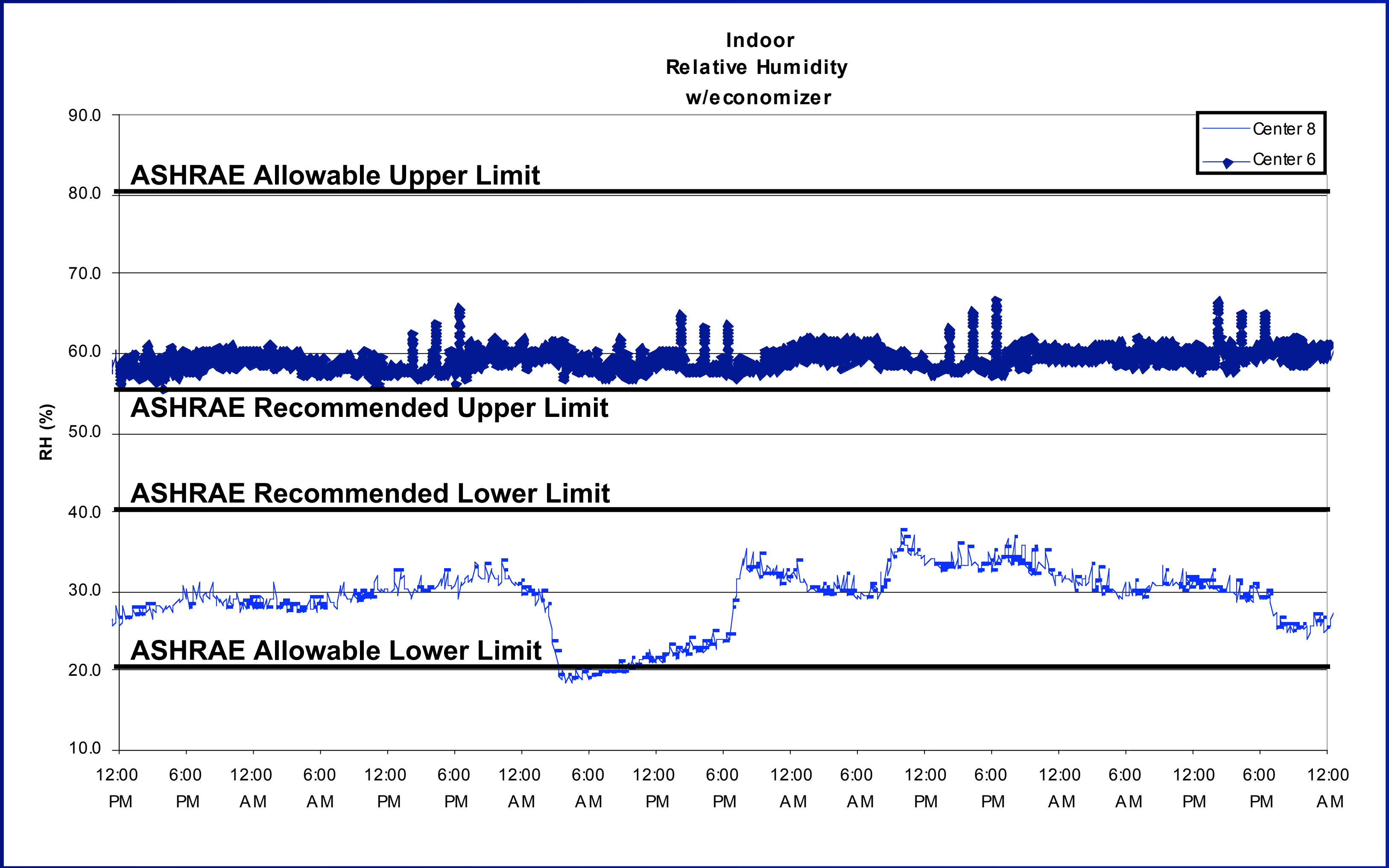
Improved Filtration



Humidity measurements without economizer



Humidity measurements with economizer



Findings

- Water soluble salts in combination with high humidity can cause failures
- It is assumed that very low humidity can allow potentially damaging static electricity
- ASHRAE particle limits are drastically lower than manufacturer standard
- Particle concentration in closed centers is typically an order of magnitude lower than ASHRAE limits
- Economizers, without other mitigation, can allow particle concentration to approach ASHRAE limits
- Filters used today are typically 40% (MERV 8) efficiency

Next steps for encouraging air economizers

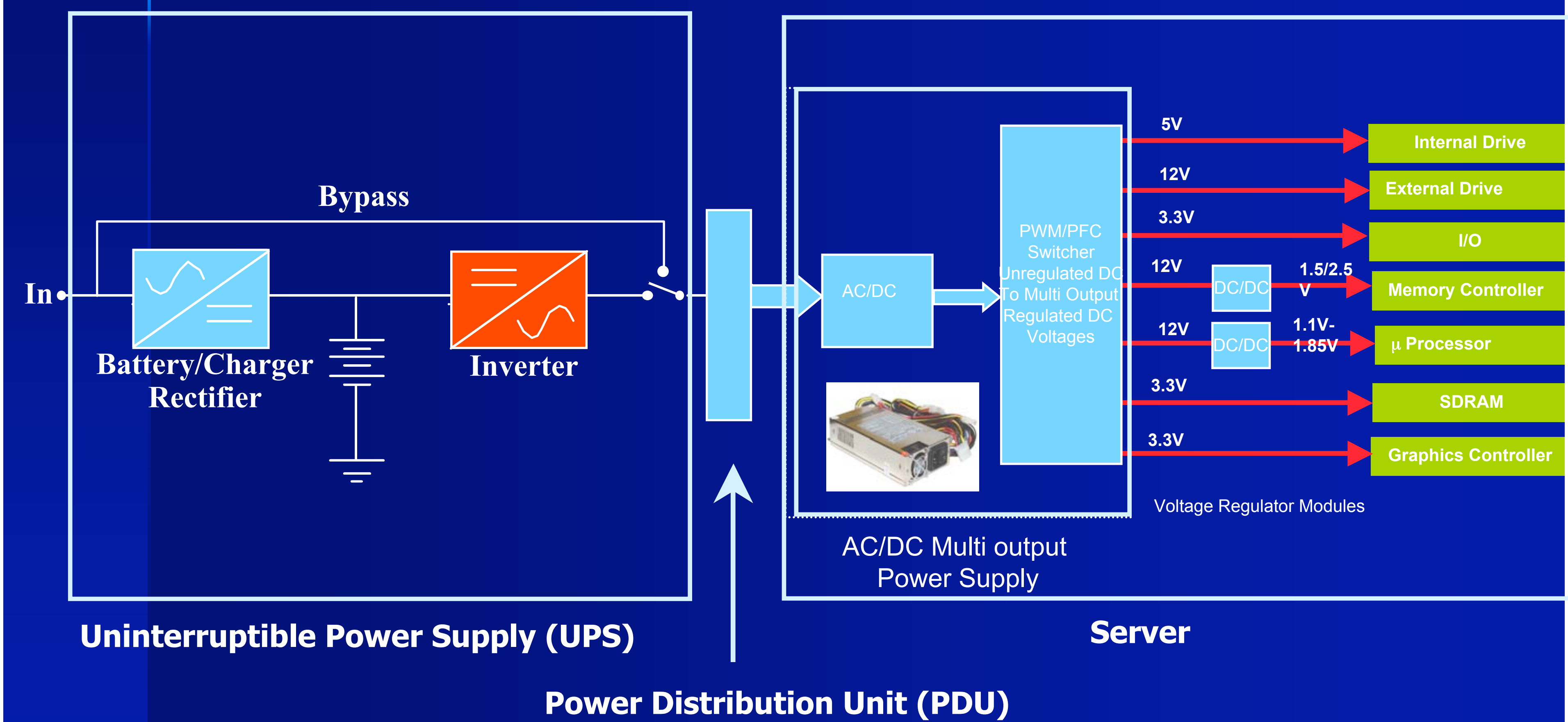
- Analyze material captured on filters
- Collaborate with ASHRAE data center technical committee
- Determine failure mechanisms
- Research electrostatic discharge
- Evaluate improved filtration options

DC powering data centers

Goal:

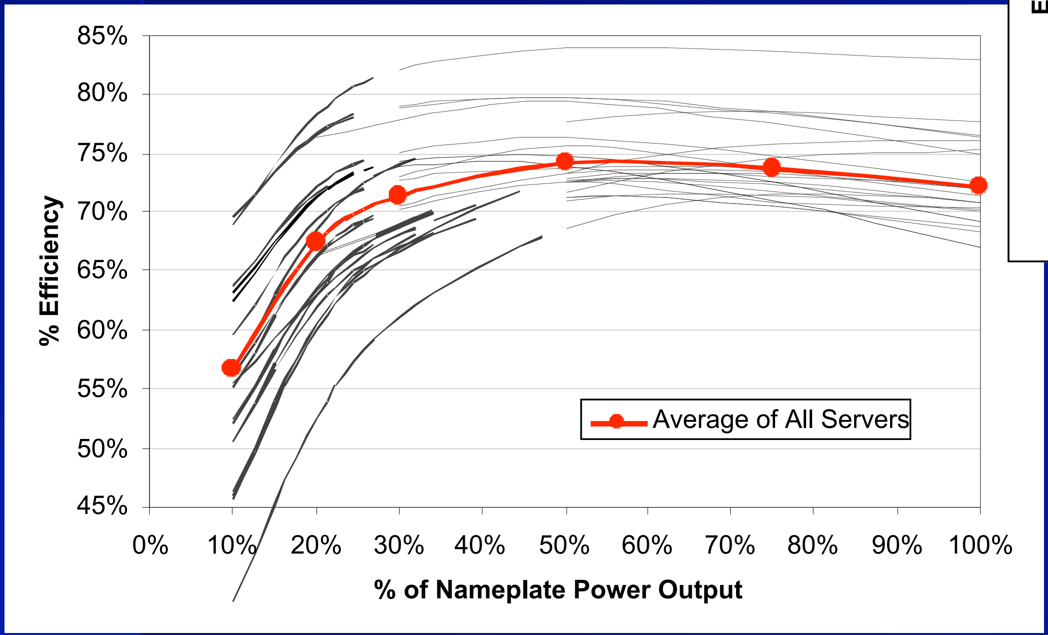
Show that a DC (direct current) system could be assembled with commercially available components. Measure actual energy savings – a proof of concept demonstration.

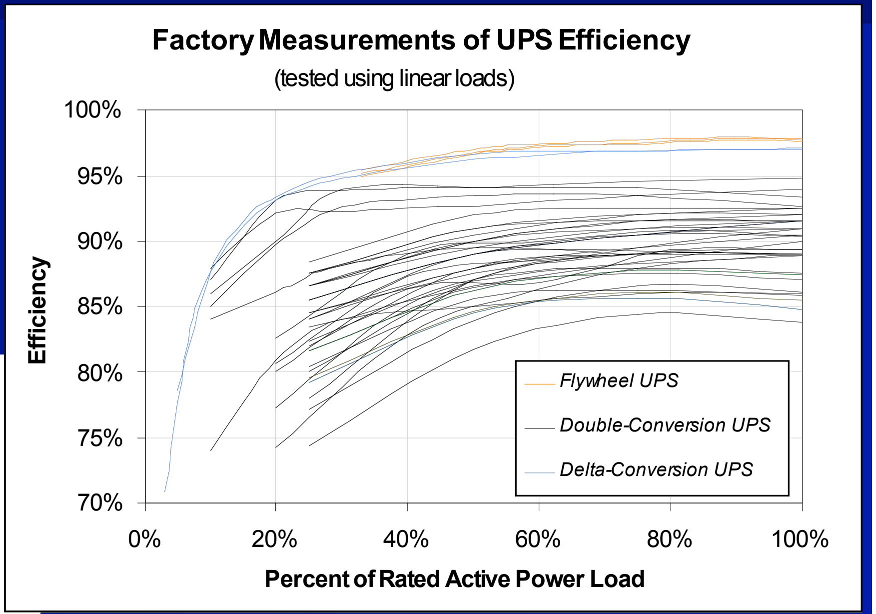
Data Center power conversions



Prior research illustrated large losses in power conversion

Power Supplies in IT equipment





Uninterruptible Power Supplies (UPS)

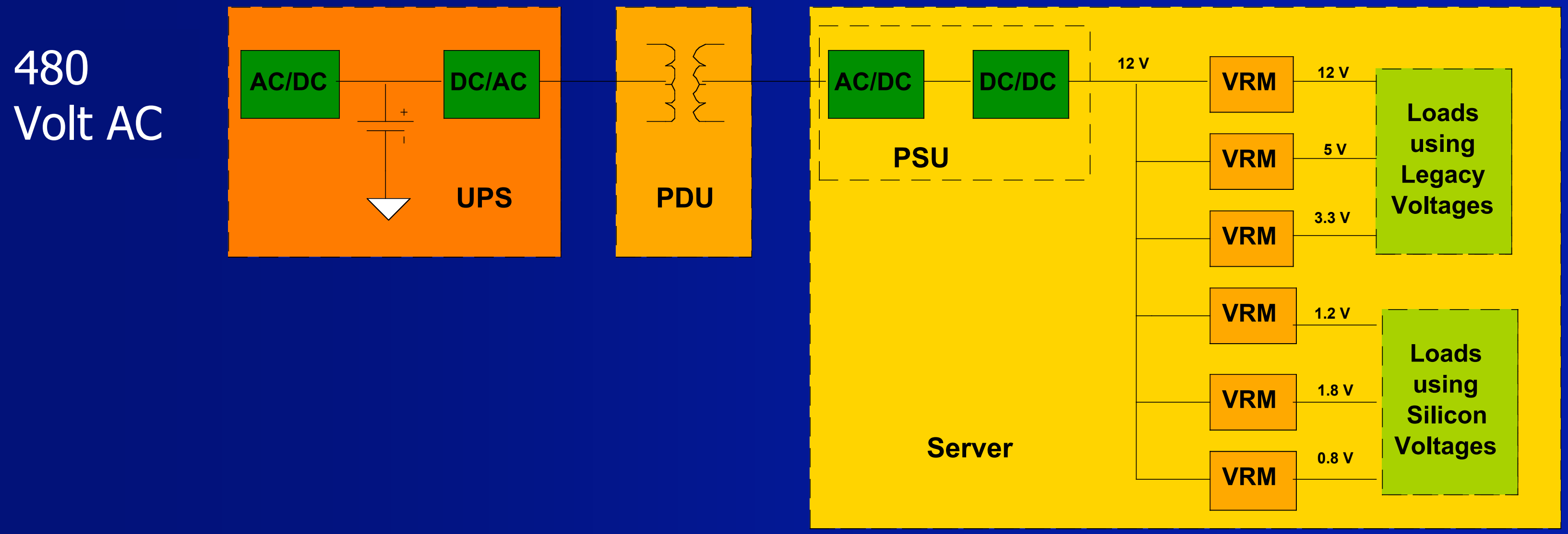
Included in the demonstration

- Side-by-side comparison of traditional AC system with new DC system
  - Facility level distribution
  - Rack level distribution
- Power measurements at conversion points
- Servers modified to accept 380 V. DC
- Artificial loads to more fully simulate data center

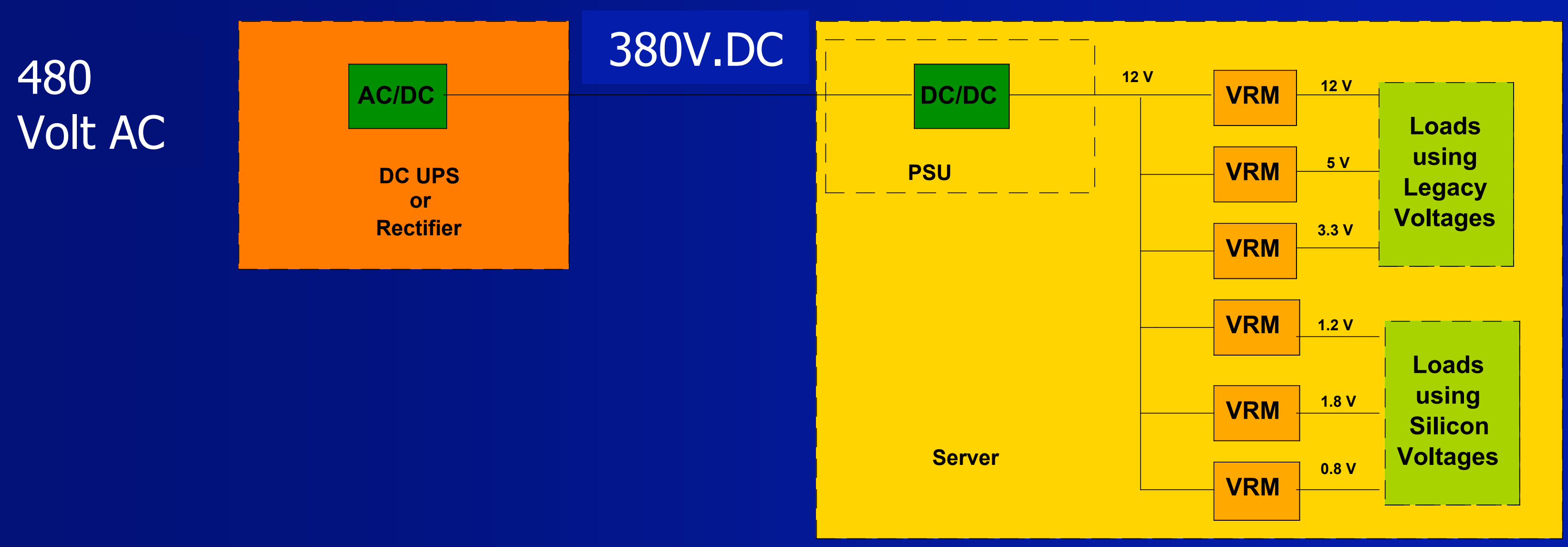
Additional items included

- 48V. DC racks to illustrate that other DC solutions are available, however no energy monitoring was provided for this configuration
- DC lighting

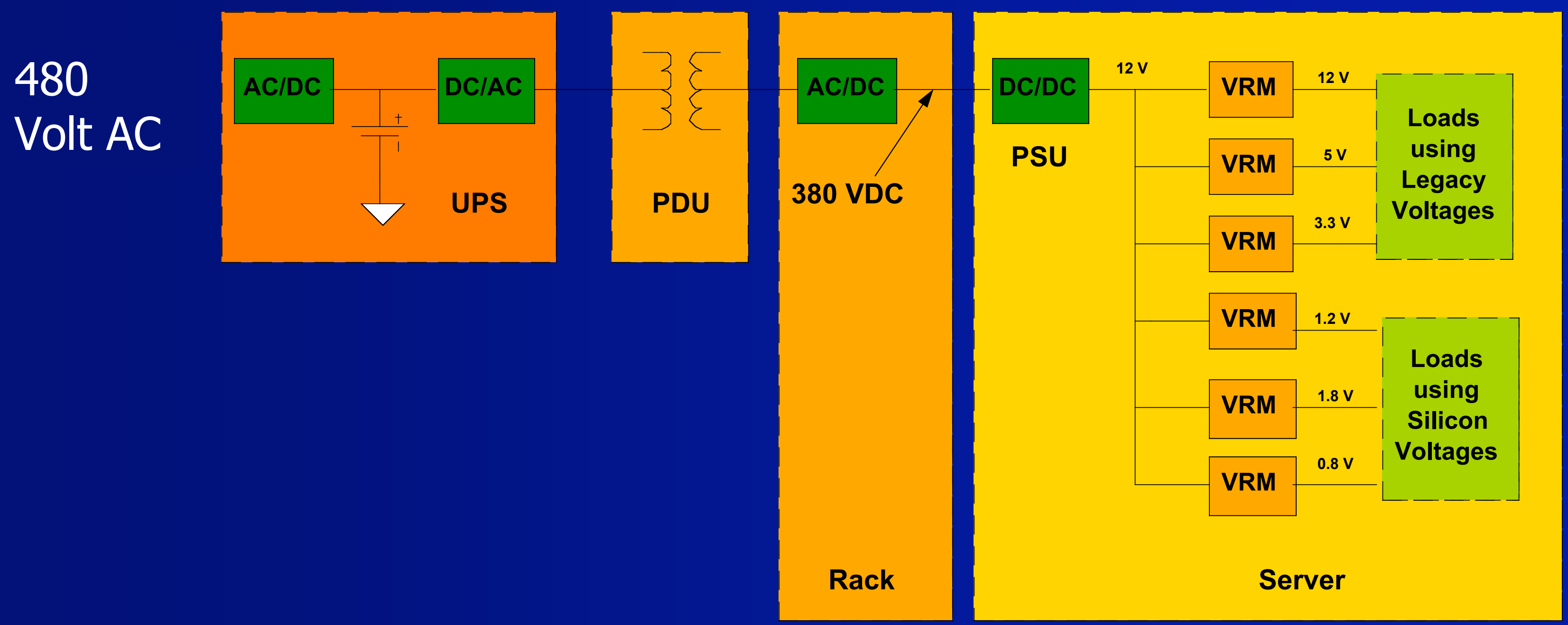
Typical AC distribution today



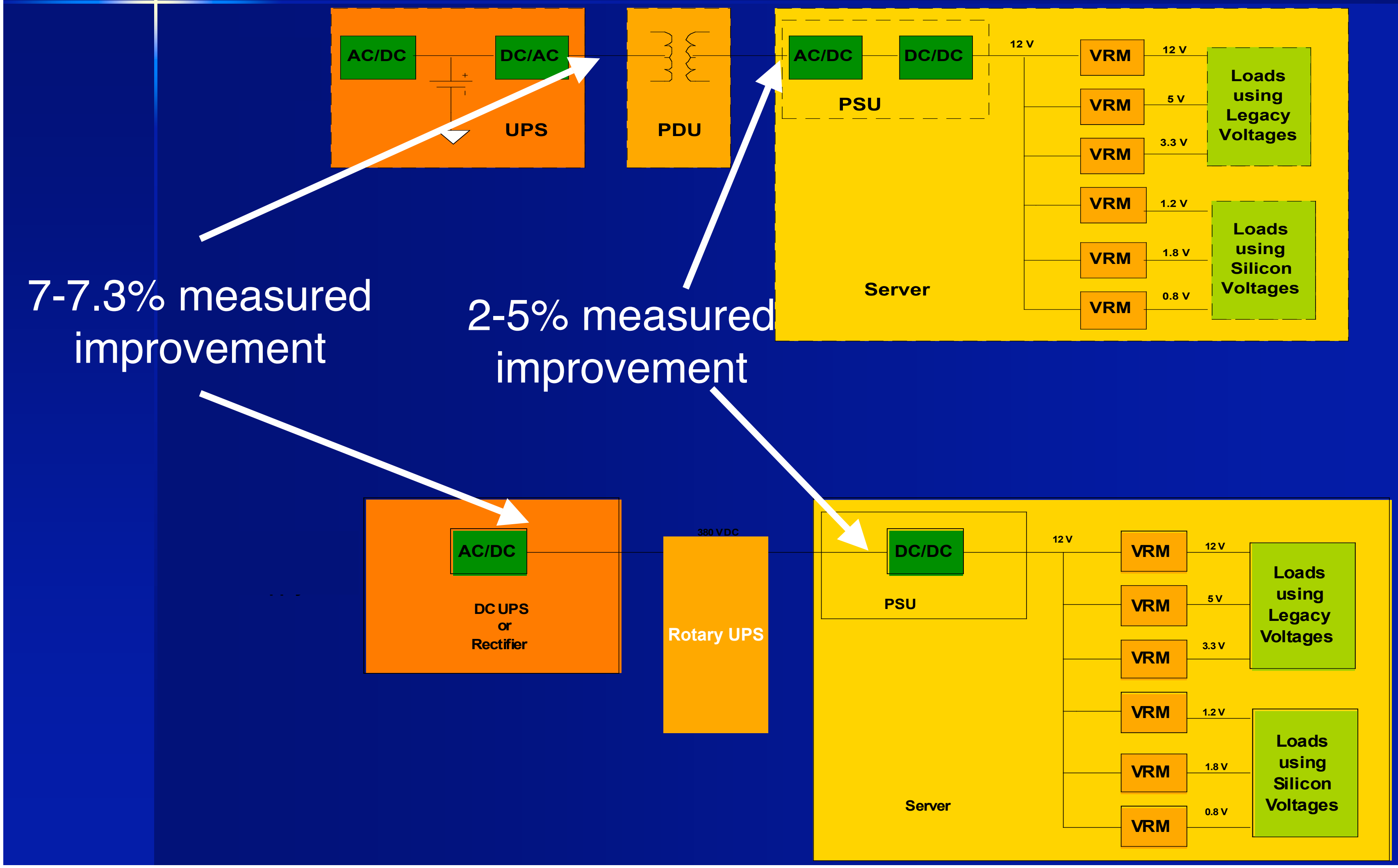
Facility-level DC distribution



Rack-level DC distribution



AC system loss compared to DC



Implications could be even better for a typical data center

- Redundant UPS and server power supplies operate at reduced efficiency

- Cooling loads would be reduced.

- Both UPS systems used in the AC base case were “best in class” systems and performed better than benchmarked systems – efficiency gains compared to typical systems could be higher.

- Further optimization of conversion devices/voltages is possible

Industry Partners in the Demonstration

Equipment and Services Contributors:

Alindeska Electrical Contractors
APC
Baldwin Technologies
Cisco Systems
Cupertino Electric
Dranetz-BMI
Emerson Network Power
Industrial Network Manufacturing (IEM)

Intel
Nextek Power Systems
Pentadyne
Rosendin Electric
SatCon Power Systems
Square D/Schneider Electric
Sun Microsystems
UNIVERSAL Electric Corp.

Other firms collaborated

Stakeholders:

380voltsdc.com
CCG Facility Integration
Cingular Wireless
Dupont Fabros
EDG2, Inc.
EYP Mission Critical
Gannett
Hewlett Packard
Morrison Hershfield Corporation
NTT Facilities
RTKL
SBC Global
TDI Power
Verizon Wireless

Picture of demonstration set-up – see video for more detail

DC power – next steps

- DC power pilot installation(s)
- Standardize distribution voltage
- Standardize DC connector and power strips
- Server manufacturers develop power supply specification
- Power supply manufacturers develop prototype
- UL and communications certification
- Opportunity for world wide DC standard

"Air Management" demonstration

Goal:

Demonstrate better cooling and energy savings through improvements in air distribution in a high density environment.

Demonstration description

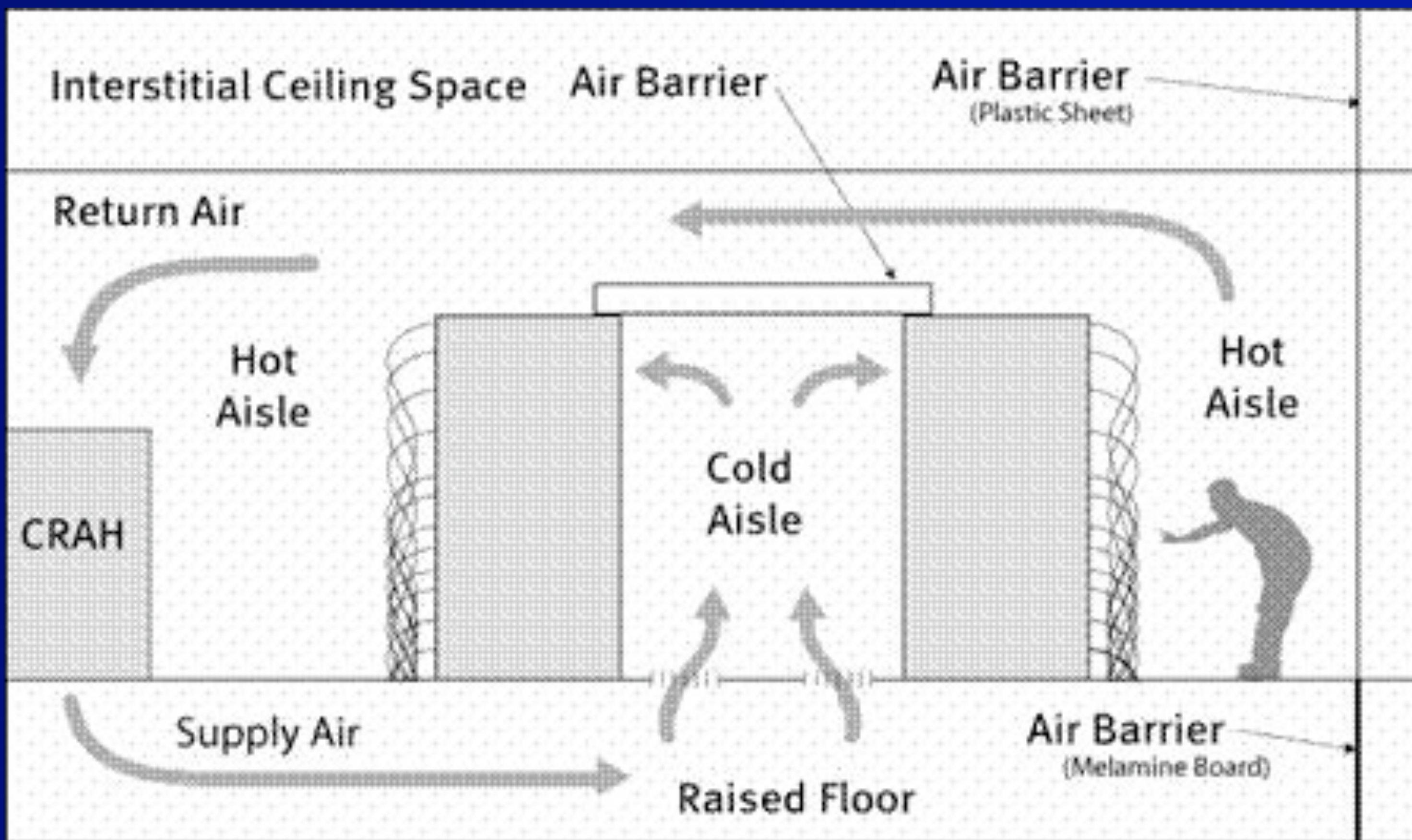
- The as-found conditions were monitored
  - Temperatures
  - Fan energy
  - IT equipment energy

- An area containing two high-intensity rows and three computer room air conditioning units was physically isolated from rest of the center – approximately 175W/sf

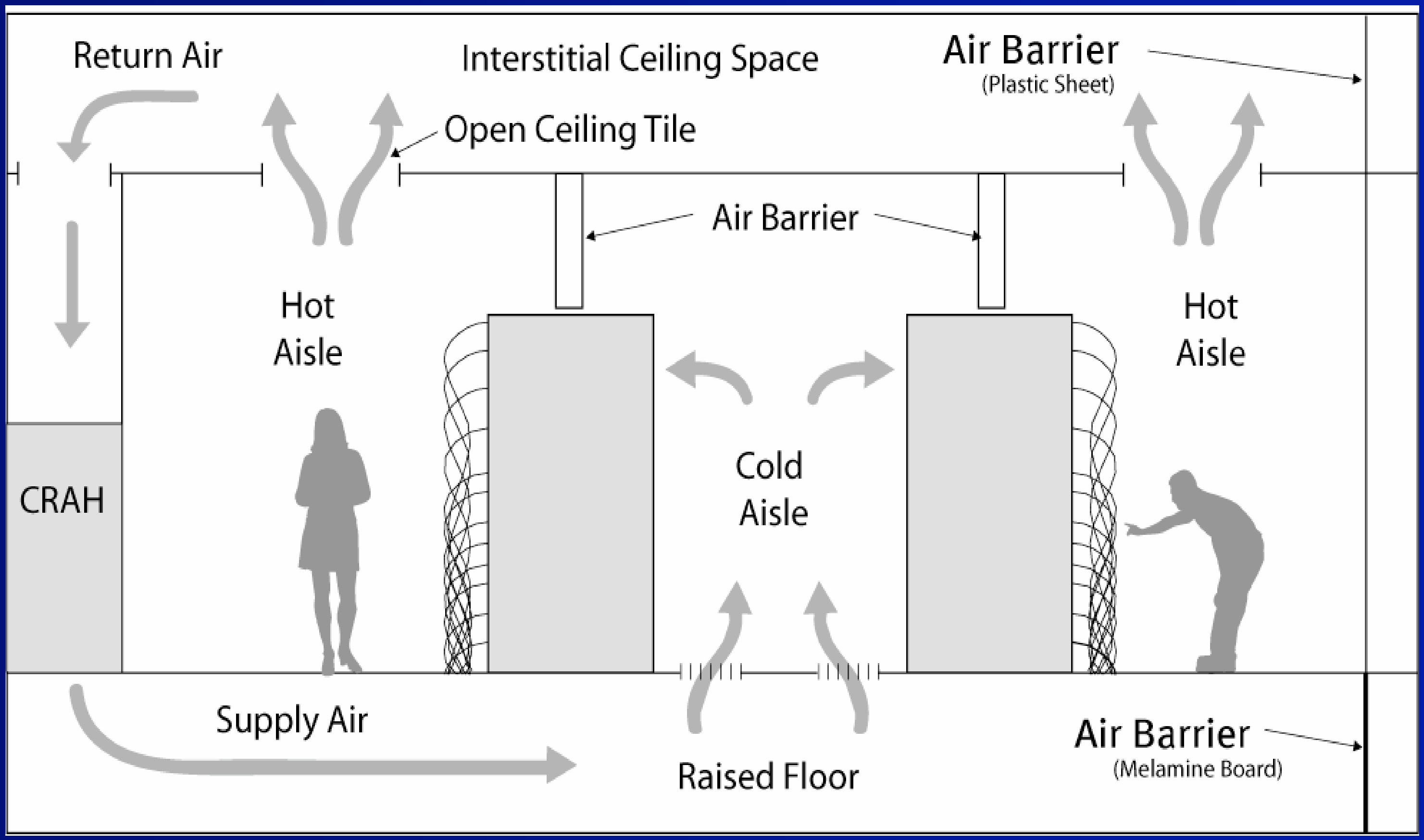
Demonstration description, con't

- Two configurations were demonstrated
- Air temperatures monitored at key points
- IT equipment and computer room air conditioner fans energy were measured
- Chilled water temperature was monitored
- Chilled water flow was not able to be measured

First configuration - cold aisle isolation



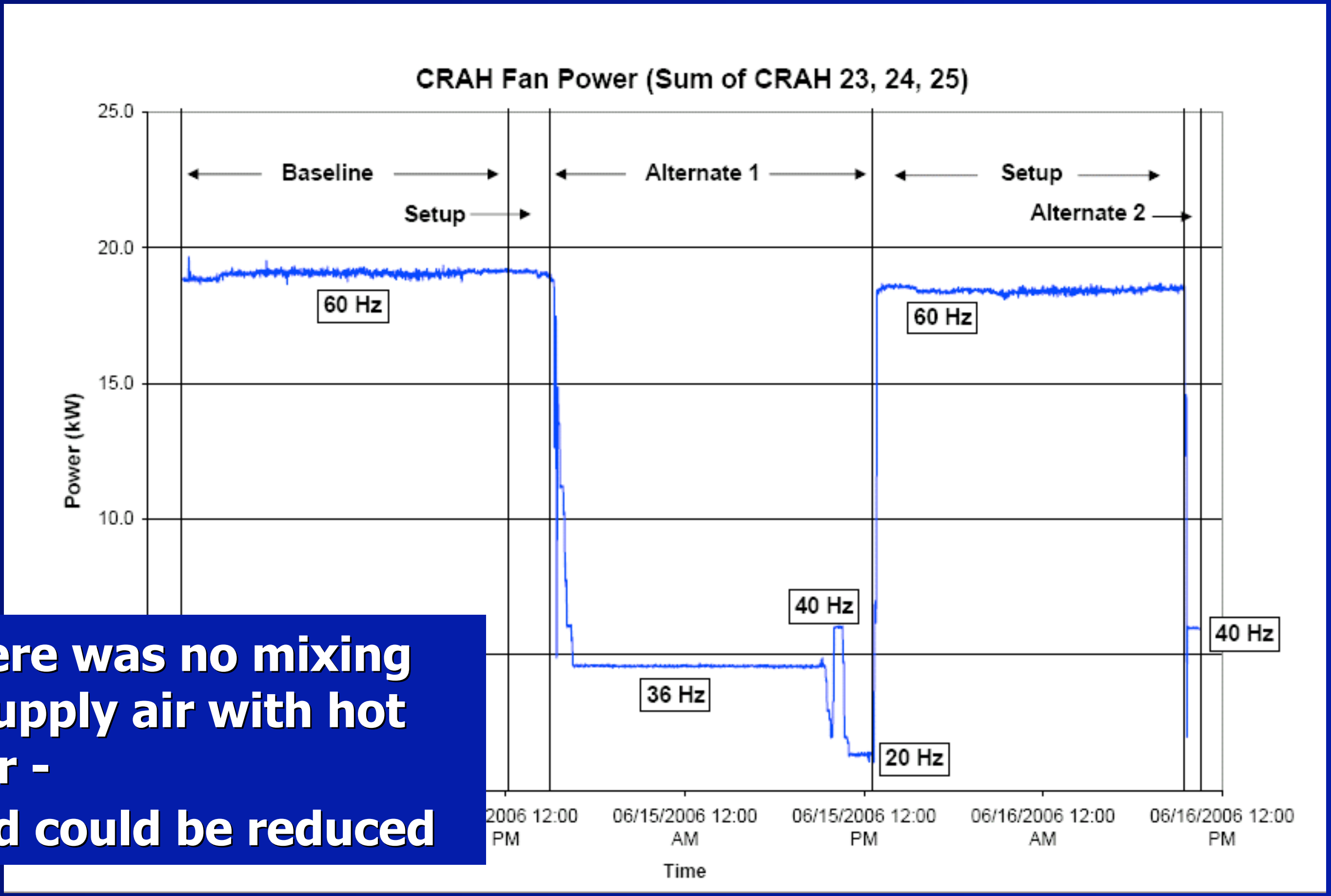
Second configuration – hot aisle isolation



Demonstration procedure

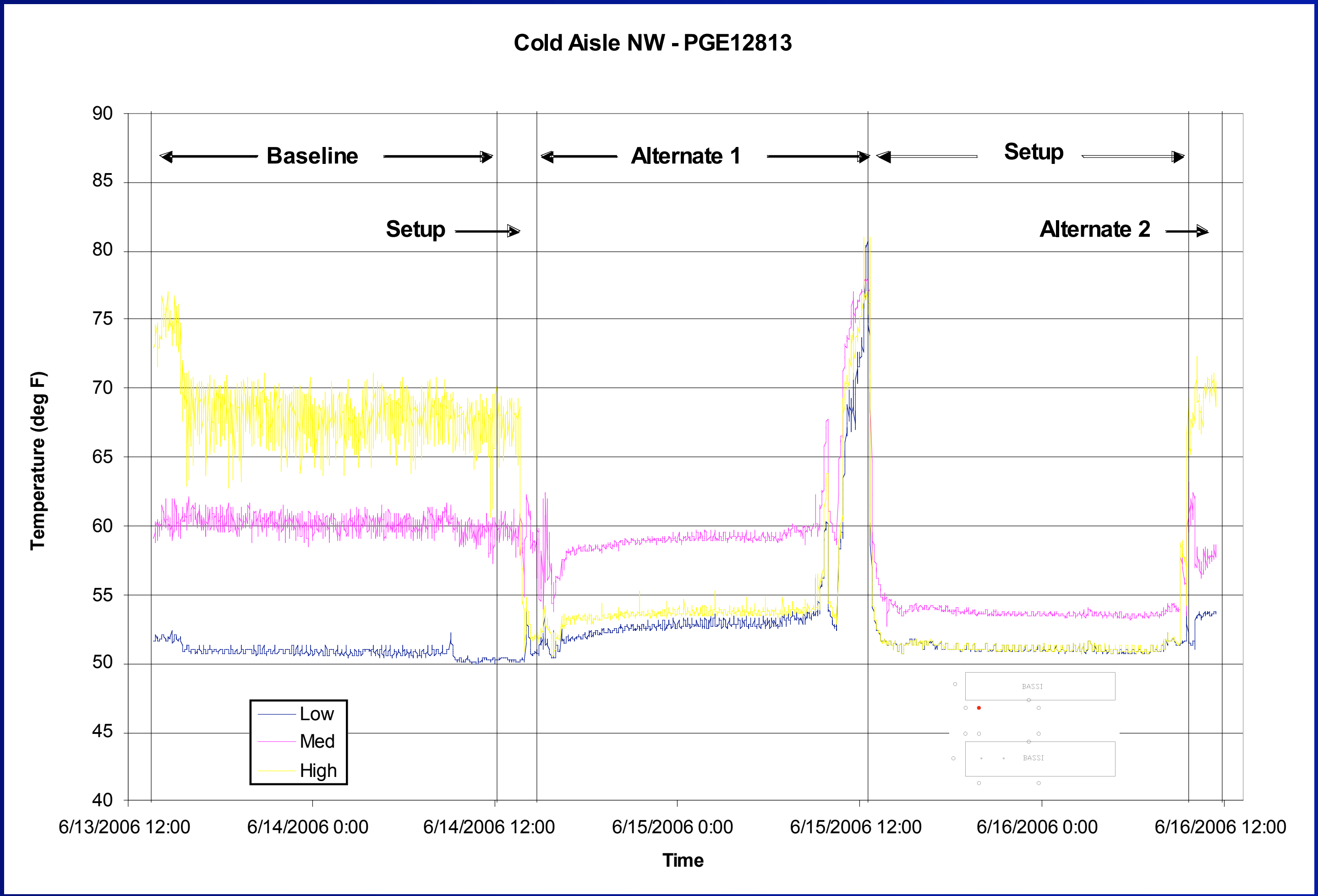
- Once test area was isolated, air conditioner fan speed was reduced using existing VFD's
- Temperatures at the servers were monitored
- IT equipment and fan energy were monitored
- Chilled water temperatures were monitored
- Hot aisle return air temperatures were monitored – ΔT was determined

Fan energy savings – 75%

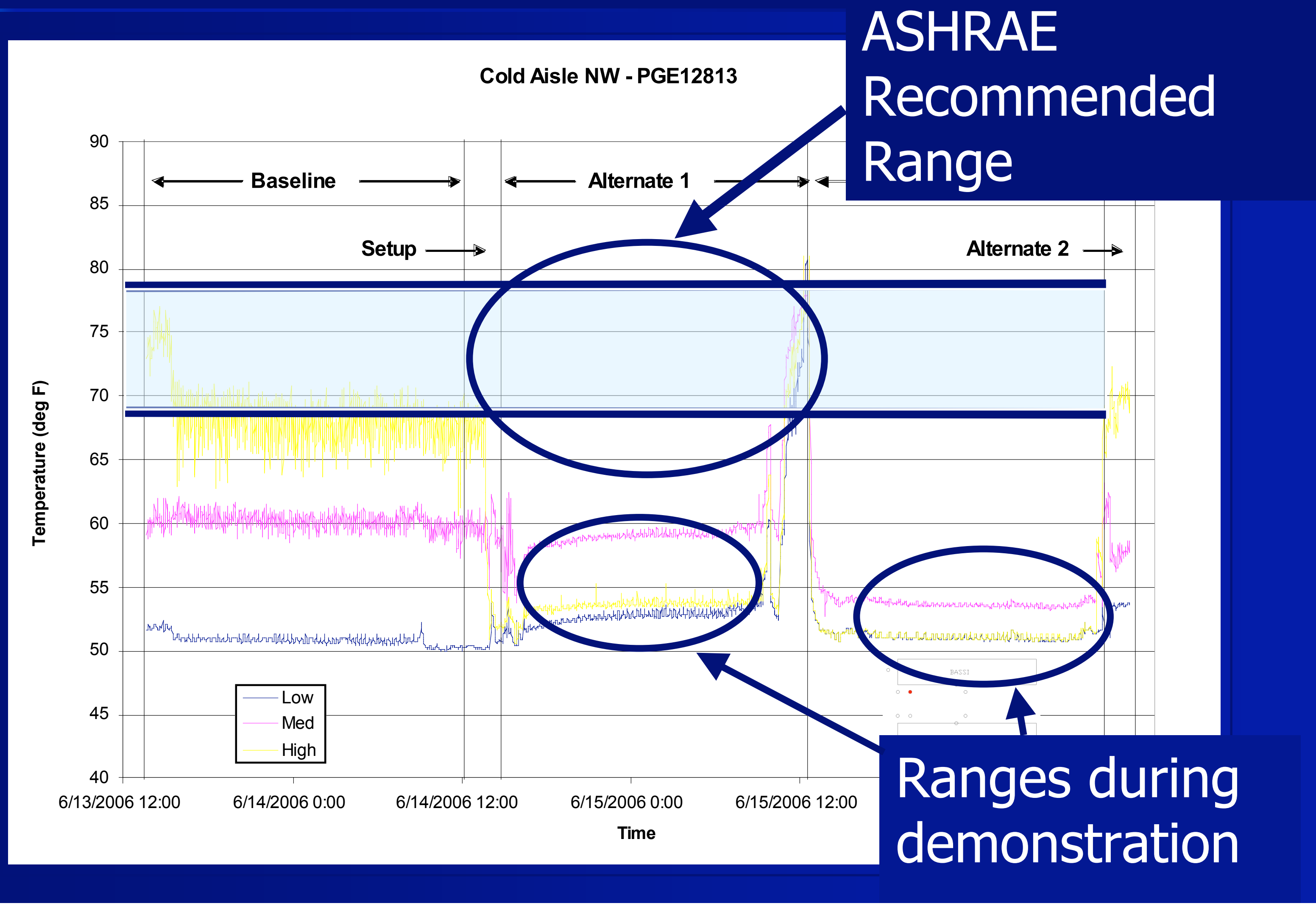


Since there was no mixing of cold supply air with hot return air -
fan speed could be reduced

Temperature variation improved



Better temperature control would allow raising the temperature in the entire data center



website:
http://hightech.lbl.gov/datacenters/

Discussion/Questions??

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Supplemental slides follow

Monitoring procedure

Approach:

- Measure data center fine particle exposure
- Determine indoor proportion of outdoor particles
- MetOne optical particle counters
- Size resolution
  - 0.3 µm, 0.5 µm, 0.7 µm, 1.0 µm, 2.0 µm, 5.0 µm
- Assume 1.5 g/cm^3 density
- Measure at strategic locations